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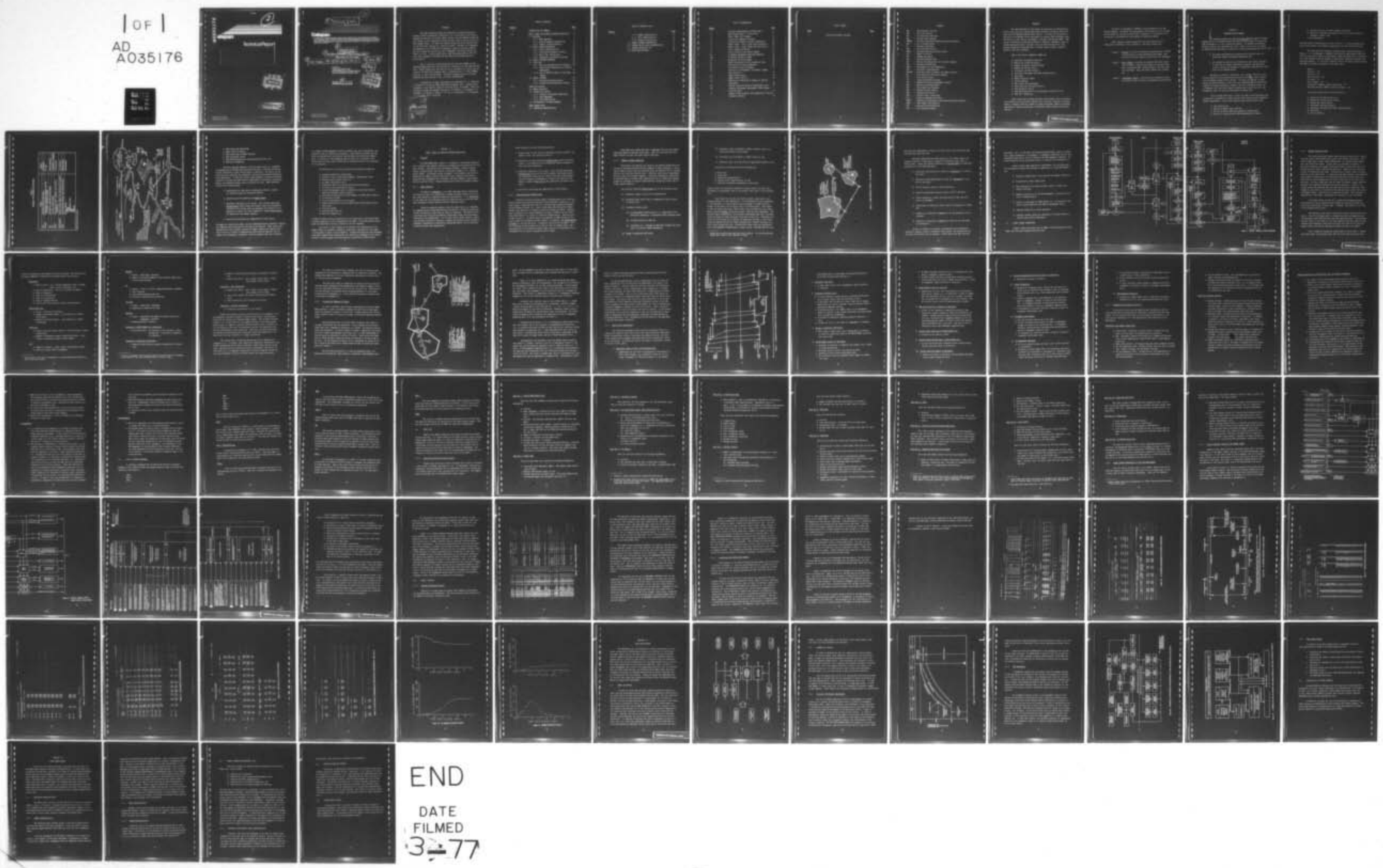

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Calspan

Technical Report

Calspan Corporation
Buffalo, New York 14221

Formerly Cornell Aeronautical Laboratory, Inc.

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SCAD SPEED MODEL.
Volume I. OVERVIEW.

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Allen H. Brown, Alexander Frueauf, Sol Kaufman [redacted] Norman Morse

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FOREWORD

The model described herein was developed by Calspan Corporation (formerly Cornell Aeronautical Laboratory, Inc.) as one task of its System Engineering Technical Assistance (SETA) contract with the AGM-86A Program Office (RW 86) of the Aeronautical Systems Division (ASD) of the Air Force Systems Command (AFSC). The model was defined during the period February 1972 to June 1972 under Contract No. F33657-72-C-0228. The model was programmed and implemented on the IBM 370/165 computer, located at Calspan, Buffalo, New York, during the period July 1972 to September 1972 under Contract No. F33657-72-C-1013. Initial model tests, comprising approximately 1300 test runs, were conducted in October 1972 and reported in Calspan Report No. TA-5175-Q-11.

Maj. J. Hassell of the Systems Analysis Division (RW86S) of the AGM-86A Program Office was the USAF monitor responsible for the model development. Threat capabilities and characteristics included in the model were defined by the SCAD Threat Working Group, co-chaired by Mr. W. Cannon (RW86S) and Capt. D. Boyer (Hq SAC/XPHN). Continuous guidance relative to threat modeling data was provided by Maj. R. Harris (Hq SAC/INEP).

Coordination of model requirements was performed by A. H. Brown and A. Frueauf of the Calspan SCAD SETA Office in Dayton, Ohio. Design and development of the model was under the direction of Dr. S. Kaufman. Major contributors to model development were Messrs. G. Gaidasz, R. B. Kruger, R. G. McLaughlin, W. Mensch, N. Morse, J. Persico, P. Przybylski, R. A. Ratajczak, W. F. H. Ring, and D. Travnicek.

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GLOSSARY

AAA	-	Anti-Aircraft Artillery
AAM	-	Air-to-Air Missile
ACI	-	Air Controlled Intercept
AEW	-	Airborne Early Warning
AFEWES	-	Air Force Electronic Warfare Evaluation Simulator
AGM	-	Air to Ground Missile
AI	-	Airborne Interceptor
ASM	-	Air-to-Surface Missile
AWACS	-	Airborne Warning and Control System
CAP	-	Combat Air Patrol
C&C	-	Command and Control
CEP	-	Circular Probable Error
CPU	-	Central Processing Unit (of a digital computer)
DGZ	-	Designated Ground Zero
DT&E	-	Development Test and Engineering
ECM	-	Electronic Countermeasures
EOB/AOB	-	Electronic Order of Battle, Air Order of Battle
EW	-	Early Warning or Electronic Warfare
FCC	-	Fire Control Center
GCI	-	Ground Controlled Intercept
LDX	-	Computer-Controlled Xerographic Plotter
O&M	-	Operations and Maintenance
PRF	-	Pulse Repetition Frequency
RPV	-	Remotely Piloted Vehicle
SAM	-	Surface-to-Air Missile
SCAD	-	Subsonic-Cruise Armed Decoy
S/J	-	Signal-to-Jamming Power Ratio
SPEED	-	Simulation of Penetrators Encountering Extensive Defenses
SRAM	-	Short Range Attack Missile
S/V	-	Survivability/Vulnerability
ZOC	-	Zone Operations Center

ABSTRACT

The model described in this report was developed by Calspan Corporation as one task of its System Engineering Technical Assistance (SETA) contract with the AGM-86A Program Office (RW 86). The model was developed on the basis of an AGM-86A system requirement to evaluate SCAD performance capabilities in a total mission environment. The model (designated SPEED - Simulation of Penetrators Encountering Extensive Defenses) complements other detailed engineering models available within the SCAD Program Office (PO), thereby providing a broad data base to support design studies, trade-off analysis, and risk assessment.

Some of the effects modeled in SPEED are:

- Penetrator and defense attrition,
- AWACS (with strobe-following),
- Command and Control System netting,
- Command and Control delays,
- Interceptor and SAM Inventory,
- Individual interceptor and radar characteristics,
- Fratricide,
- SRAMs and gravity bombs,
- Terrain masking,
- ECM strobes and burnthrough,
- SCAD launch and in-flight failures,
- SCAD navigation errors,
- SCAD ECM characteristics and ECM Module reliability, and
- SCAD fuel consumption.

Model output data includes printouts and automatic plots of detailed time histories and statistical summaries for a variety of measures including number of bombers surviving, number of weapons delivered, number of encounter opportunities against penetrators, and detailed offense-defense interaction measures.

The model is programmed in FORTRAN IV and implemented on an IBM 370/165 computer. The model uses approximately 400 kilobytes of core storage and 30-seconds of central processor time to simulate a 5.5 hour mission involving up to 100 penetrators and hundreds of defensive elements.

Three separate volumes document the use and structure of the SPEED model in different levels of details. The three volumes are:

Volume 1 - Overview, in which the essential characteristics of SPEED I, applicability to SCAD engineering development, and directions for model growth are described (this document),

Volume 2 - Users' Manual, containing an expanded functional exposition of SPEED I, detailed description of required input data, assumptions made, effects modeled, and output measures provided. Input and output samples are included, and

Volume 3 - Programmers' Manual, containing source program listings, job control setup, and special programming considerations.

SECTION I

INTRODUCTION AND SUMMARY

This document presents an overview of the model developed by Calspan Corporation for the AGM-86A Program Office to provide a means for evaluating SCAD performance in a total mission environment. The AGM-86A System Specification contains the requirement for such a model to be used in the course of AGM-86A System development, acquisition, and operation/employment for the following:—

- the timely determination of quantitatively optimal values of System and Segment performance parameters, and

- the comparative evaluation of alternatives and change proposals in the areas of design, performance, logistics and operations, tactics, threats and scenarios, as applicable throughout the life cycle of the AGM-86A System.

The model was defined, implemented, and tested as one task of the Calspan Corporation System Engineering Technical Assistance (SETA) contract with the AGM-86A Program Office (RW 86). The model was defined in detail during the period February to June 1972, was implemented on the IBM 370/165 computer at Calspan Corporation, Buffalo, New York, during the period July to September 1972, and initial model validation and sensitivity tests (approximately 1300 test runs) were performed in October 1972.

Prior to model definition, a survey was made of existing models and simulations to determine if a model existed which could be easily adapted to AGM-86A requirements. Some of the required model characteristics were:

- fast running time,
- ability to handle large scenarios,
- ability to handle individual penetrator flight paths,
- ability to accept detailed SCAD engineering data inputs,

- compatibility with available computer facilities,
- adaptable to AGM-86A requirements within the allocated model development schedule, and
- well-documented.

The major models investigated are listed in Table I. It was determined that none of these models were completely appropriate for the stated conditions.

The SPEED model was therefore developed and is shown pictorially in Figure 1. It is programmed in FORTRAN IV and requires approximately 400 kilobytes of core and 30-seconds of IBM 370/165 central processor time to simulate a 5.5 hour mission involving hundreds of penetrators, penetrator weapons, and defensive elements. In one of the scenarios used in the model validation tests, the number of elements considered in the model were:

AWACS - 1
EW Sites - 119
GCI Sites - 50
SAMs (5 types) - 271
Air Bases - 15
AIs (6 types) - 271
Penetrators (bombers, SCADs, Hound Dogs) - 76
Penetrator Weapons (SRAMs and Gravity Bombs) - 120

Other major modeled effects and elements are:

- penetrator and defense attrition,
- command and control system netting,
- command and control delays,
- interceptor and SAM inventory,
- individual interceptor and radar characteristics,
- fratricide,
- terrain masking,

TABLE I

MISSION TYPE MODELS SURVEYED

MODEL		AGENCY
APM	ADVANCED PENETRATION MODEL	USAF/BOEING
PEGASOS	PENETRATION EVALUATION GAMING ANALYSIS STRATEGIC OFFENSIVE STUDIES	HQ USAF
ACE	AUTONETICS CAMPAIGN EFFECTIVENESS	NORTH AMERICAN
TDM	TACTICAL DIGITAL MODEL	FTD/GENERAL DYNAMICS
MECCA	MODELING OF ENEMY COMMAND AND CONTROL ATTRIBUTES	AFAL/CALSPAN
BOOKKEEPING	MISSION EVENTS MODEL FOR PENETRATING AIRCRAFT	AFAL/CALSPAN
QUICK	QUICK-REACTING GENERAL WAR GAMING SYSTEM	NMCSSC/LAMBDA
	PENVAL* MODELS –MPASS –THESIS –TIMBERLINE/ TITAN –EOB –DSD –SNOOPER	AFAL/CALSPAN

*PENETRATION AIDS EVALUATION

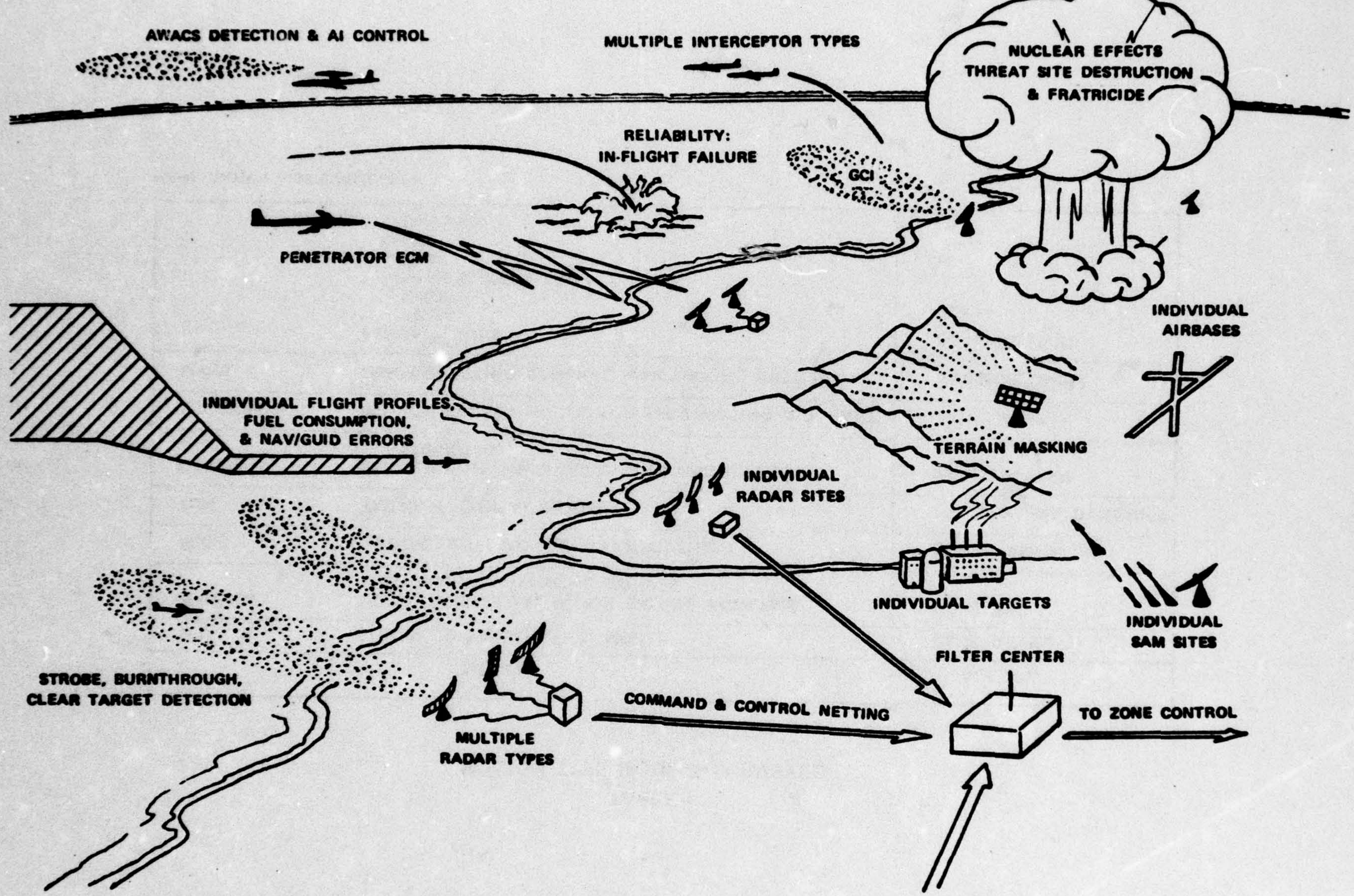

Figure 1 PICTORIAL REPRESENTATION OF SPEED MODEL (SIMULATION OF PENETRATORS ENCOUNTERING EXTENSIVE DEFENSES)

- ECM strobes and burnthrough,
- AWACS strobe following,
- SCAD launch and in-flight failures,
- SCAD navigation errors,
- SCAD ECM characteristics and ECM module failures, and
- SCAD fuel consumption.

The basic approach adopted is that the model serves as a framework for aggregating and integrating detailed one-on-one or localized interaction results introduced as input look-up tables or functions. The latter are derived from prior analyses and simulations, using real-time manned simulations where appropriate. In this way, fairly large scenarios, involving individual trajectory lay-downs and SCAD vehicles represented in substantial engineering detail, are simulated quickly and at relatively low cost. Model operation involves the following steps:

- Preprocessing of input data on penetrating vehicles, weapons, air defense system, and interaction effects.

- Generation and time-ordering of <u>Primary Events</u>.

- Sequential simulation of all events - this includes generating <u>Derived Events</u> (which along with primary events are subsequently simulated at the proper time) and determine the interactive consequences of events; the latter embodied in updated <u>State Vectors</u> for penetrators and defense elements.

- Statistical processing and summarization of data outputs.

The model is a Monte Carlo model, and two-standard-deviation confidence intervals are computed within the model for the major test measures. Model output data includes such overall mission measures as bomber survival and weapons delivered as well as a variety of progressively more detailed measures, such as number of AI assignments, encounters, and kills against each type of penetra-

tor, number of SAM engagements and kills against each type of penetrator, and percent of time the defenses are saturated. Both computer printouts and LDX plots are provided for both detailed time histories and statistical summary data. In addition to this aggregate data for each set of replicates a detailed event-by-event output listing may be obtained for any or all replicates as a user option.

The SPEED model was initially based on the following assumptions:

- preplanned penetrator flight paths,
- constant velocity flight path segments, instantaneous turns,
- offense weapons produce total kill,
- no bomber navigation errors,
- simplified radar cross section and antenna gain tables,
- no explicit discrimination of decoys,
- AI and SAM engagement and kill probabilities derived from more detailed simulations and/or analyses,
- known EOB and AOB (portion of EOB unknown to flight path planners),
- no intercept of SRAM,
- AIs are reassignable but not recycled,
- threat characteristics based on SCAD threat working group intelligence data,
- stationary AWACS,
- present bomber ECM, and
- main-lobe jamming only.

A number of these limiting assumptions will be eliminated in the planned modifications/expansions to be incorporated in the model. The planned model growth areas are described in detail in Section IV of this document.

The intent of this document is to provide a full description of the SPEED I Model, as currently configured, along with a delineation of the scope of study areas to which it may be applied. Although the model has been developed under SCAD Program Office sponsorship, its versatility recommends it for consideration by other programs requiring analysis of penetration effectiveness.

SECTION II

SPEED I MODEL AND COMPUTER PROGRAM DESCRIPTION

2.1 OVERVIEW

The SCAD SPEED Model concept is a stochastic, event-based simulation of air vehicles (and weapons) penetrating through and interacting with air defense systems. Penetrating vehicles/weapons encompass: manned aircraft, drones, airborne decoys, and various air-launched ordnance, viz., ASM and gravity bombs. Air defense systems encompass: area defenses (specifically, ground EW net, AWACS, airborne interceptors [AI], airbases, GCI stations, along with the integrating C&C structure), and point defenses (specifically SAM sites and AAA sites). Weapon targeting can include air-defense elements.

2.1.1 Model Approach

The model is stochastic in the sense that many factors influencing the course of events are represented as random variables sampled in accordance with inputted or computed probability distributions. It is event-based in the sense that the simulation sequences from key event to next key event, hence accepting variable intervals between simulation steps.

The basic approach adopted is that the model serves as a framework for aggregating and integrating detailed one-on-one or localized interaction results introduced as input look-up tables or functions. The latter are derived from prior analyses and detailed simulations (using real-time manned simulations where appropriate). In this way, fairly large scenarios, involving individual penetrator trajectory laydowns and offensive and/or defensive components represented in substantial engineering detail, can be simulated relatively quickly and inexpensively.

Model operation involves the following steps:

- Preprocessing of input data on penetrating vehicles, weapons, air defense system, and interaction effects.

- Generation and time-ordering of Primary Events (which constitute a more or less minimal set of precomputable events necessary to drive the total simulation).

- Sequential simulation of all events - this includes generating Derived Events along the way which together with primary events are subsequently simulated (in correct time order) and determining the interactive consequences of events; the latter are embodied in updated State Vectors for penetrators and defense elements.

- Statistical processing and summarization of data outputs.

2.1.2 Problem Dimension Capabilities

Currently allocated storage permits representation of up to 100 air-defense-system-interacting penetrators of three different classes (e.g., aircraft, decoys, long-range ASM) and up to 100 additional penetrators/weapons of two different classes (e.g., small, short-range ASM, and gravity bombs). Scenario time duration is currently restricted to about 8.5 hours. Scenario area is unlimited, but linear dimensions in excess of 2000 n.mi. may introduce distortions of $\sim$2 percent in distances between points. There are provisions for up to: 120 EW/GCI radar site complexes or AWACS (which can include as many as 75 distinct GCI/ACI centers), 70 airbases, 200 simultaneously-in-flight AI, and 300 SAM sites. (Currently, AAA sites are excluded.) The C&C system may be partitioned into as many as five air defense zones, each represented by a zone operations center (ZOC), and up to 35 subcontrols (i.e., intermediate filter centers linking EW sites to ZOCs).

Each radar site complex may have a complement of up to five radars drawn from among 20 different radar types. There are also provisions for eight distinct AI types and eight distinct SAM types.

2.1.3 Summary of Model Operation

Penetrators are inputted and stored as pre-planned flight paths consisting of connected constant-velocity segments in three dimensions - starting at launch or entry into the simulated area, and ending at DGZ or terminal point or exit from the simulated area. (Ballistic paths may be approximated by such a series of straight segments.) One type of penetrator (identified as the SCAD decoy in current model application) has its flight path randomly deleted or perturbed to reflect launch failures, navigation errors, and in-flight vehicle failures.

The initially computed Primary Events are of the following types:

(1) Penetrator launch or entry into simulated area

(2) Penetrator check point (turn, or beginning or end of ascent or descent leg)

(3) Penetrator terminal point

(a) Pre-programmed terminal point (i.e., weapon DGZ, final penetrator checkpoint, or penetrator exits simulated area)

(b) In-flight failure or fuel-out

(c) Fratricide (i.e., passage of penetrator through the active zone of an earlier weapon detonation)

(4) Change in penetrator ECM status

(5) Penetrator entry into EW/GCI or AWACS visibility zone (i.e., unobstructed radar line-of-sight)

(6) Penetrator exit from EW/GCI or AWACS visibility zone

(7) Penetrator entry into SAM visibility and weapon-capability zone.

Each event is represented by the following data:

- Event type
- Event time*
- Penetrator identification*
- Defense entity identification (if any)
- Auxiliary information (depending on event type)

Figure 2 shows an illustrative sequence of primary events (in plan view). The numbers in parentheses refer to the primary event types in the preceding list.

Event types (1), (2) and (3) (initial points, check points, and terminal points) are self-explanatory. For one penetrator class (identified as the SCAD decoy in current application) programmed or random (failure) changes in ECM status are carried as type (4) primary events. With respect to the last three event types, EW/GCI radar sites and SAM sites have individually inputted maximum terrain mask angles, based on local topography. Random mask angles independently and uniformly distributed from zero to maximum value are drawn for eight principal directions of each site. Penetrator visibility (line-of-sight) as a function of penetrator altitude is then determined and thereby defines (by linear interpolation) "random" octagonal visibility zones around each site. For SAM sites, these zones are intersected with (type-dependent) maximum missile range circles. Although SAM exits are

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* Penetrator identification and event time, together with stored penetrator flight path, serve to fix location of event.

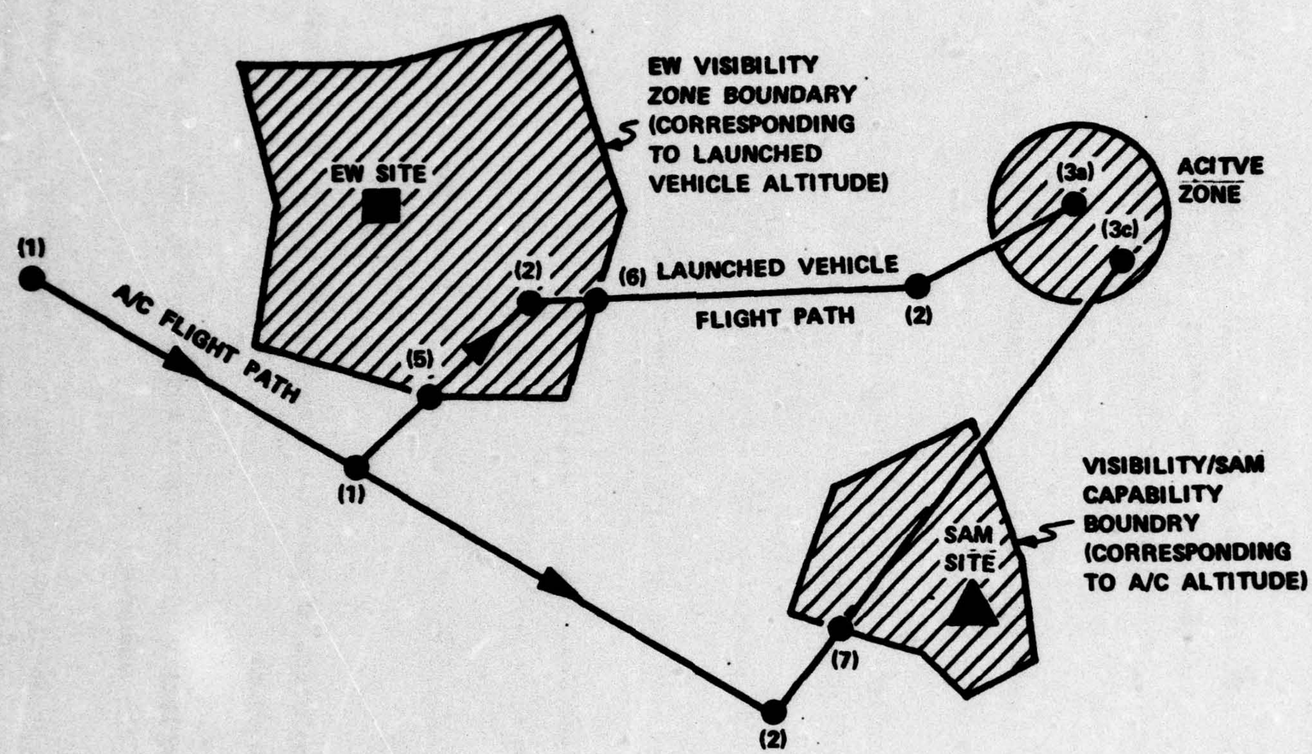


Figure 2 SOME PRIMARY EVENTS – IN PLAN VIEW

not explicitly represented as events, the entry events carry along with them time duration within the zone.

Following computation and time-ordering of all primary events, the simulation process is executed as a sequential operation on all events in correct order. During this process additional or Derived Events are generated, and these are of the following types:

1) Penetrator clear detection by radar site subsequent to visibility zone entry

2) Penetrator strobe burnthrough by radar site subsequent to visibility zone entry

3) Initial detection report by EW to subcontrol

4) Strobe-to-burnthrough detection report by EW to subcontrol

5) Target designation, target track initiation at ZOC, and (possible) AI assignment

6) Reassessment of penetrator target track for subsequent AI assignment

7) Completion of penetrator engagement by AI and assessment of consequences

8) Completion of penetrator engagement by SAM site and assessment of consequences

As may be inferred by the above, superimposed on the penetrator's trajectory sequence (launch, intermediate check points, and termination) are two major interrelated sets of sequences - which repeat with many detailed

variations - viz., (i) EW entry (and detection/burnthrough), report to subcontrol, target designation, AI assignment, AI engagement completed, EW exit (and subsequent break-track); and (ii) SAM entry and SAM engagement completed. Detailed discussion of the simulation process is deferred until paragraph 2.2.

To meet current model application requirements, the following tabular and graphical outputs are provided on completion of a replicated SPEED I run:

1) Penetrator (bomber/decoy) attrition data and summary statistics

2) Distribution of decoy ranges flown

3) Time histories of surviving aircraft, decoys in flight, and weapons delivered

4) Summary statistics on AI and SAM engagements, conversions, and kills vs bombers/decoys

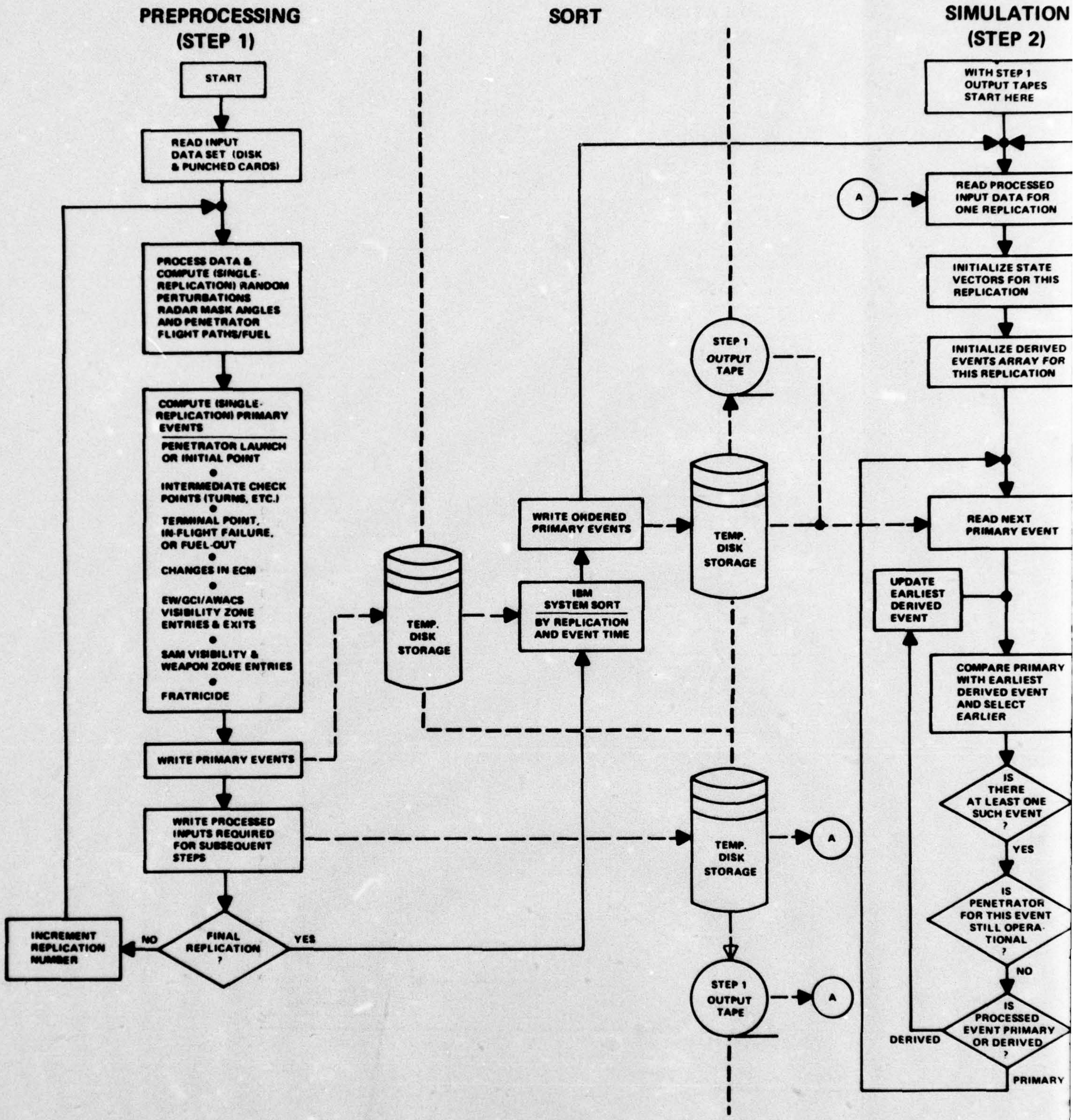
5) Portion of time spent by bomber/decoys in: no-interaction, C&C delay, system saturation, and under-AI-engagement states

6) Detailed record of all events processed

7) Periodic records, during the simulation, of current values of selected state vectors (optional).

2.2 SPEED I MODEL DESCRIPTION

Figure 3 shows the overall flow of SPEED I with partitioning of the model into four major program execution steps.



PREPROCESSING (STEP 1)
SORT
SIMULATION (STEP 2)
START
READ INPUT DATA SET (DISK & PUNCHED CARDS)
PROCESS DATA & COMPUTE (SINGLE-REPLICATION) RANDOM PERTURBATIONS RADAR MASK ANGLES AND PENETRATOR FLIGHT PATHS/FUEL
COMPUTE (SINGLE-REPLICATION) PRIMARY EVENTS
PENETRATOR LAUNCH OR INITIAL POINT
INTERMEDIATE CHECK POINTS (TURNS, ETC.)
TERMINAL POINT, IN-FLIGHT FAILURE, OR FUEL-OUT
CHANGES IN ECM
EW/GCI/AWACS VISIBILITY ZONE ENTRIES & EXITS
SAM VISIBILITY & WEAPON ZONE ENTRIES
FRATRICIDE
WRITE PRIMARY EVENTS
WRITE PROCESSED INPUTS REQUIRED FOR SUBSEQUENT STEPS
FINAL REPLICATION ?
NO
YES
INCREMENT REPLICATION NUMBER
TEMP. DISK STORAGE
IBM SYSTEM SORT
BY REPLICATION AND EVENT TIME
WRITE ORDERED PRIMARY EVENTS
TEMP. DISK STORAGE
STEP 1 OUTPUT TAPE
TEMP. DISK STORAGE
A
STEP 1 OUTPUT TAPE
A
WITH STEP 1 OUTPUT TAPES START HERE
A
READ PROCESSED INPUT DATA FOR ONE REPLICATION
INITIALIZE STATE VECTORS FOR THIS REPLICATION
INITIALIZE DERIVED EVENTS ARRAY FOR THIS REPLICATION
READ NEXT PRIMARY EVENT
UPDATE EARLIEST DERIVED EVENT
COMPARE PRIMARY WITH EARLIEST DERIVED EVENT AND SELECT EARLIER
IS THERE AT LEAST ONE SUCH EVENT ?
YES
IS PENETRATOR FOR THIS EVENT STILL OPERATIONAL ?
NO
IS PROCESSED EVENT PRIMARY OR DERIVED ?
DERIVED
PRIMARY

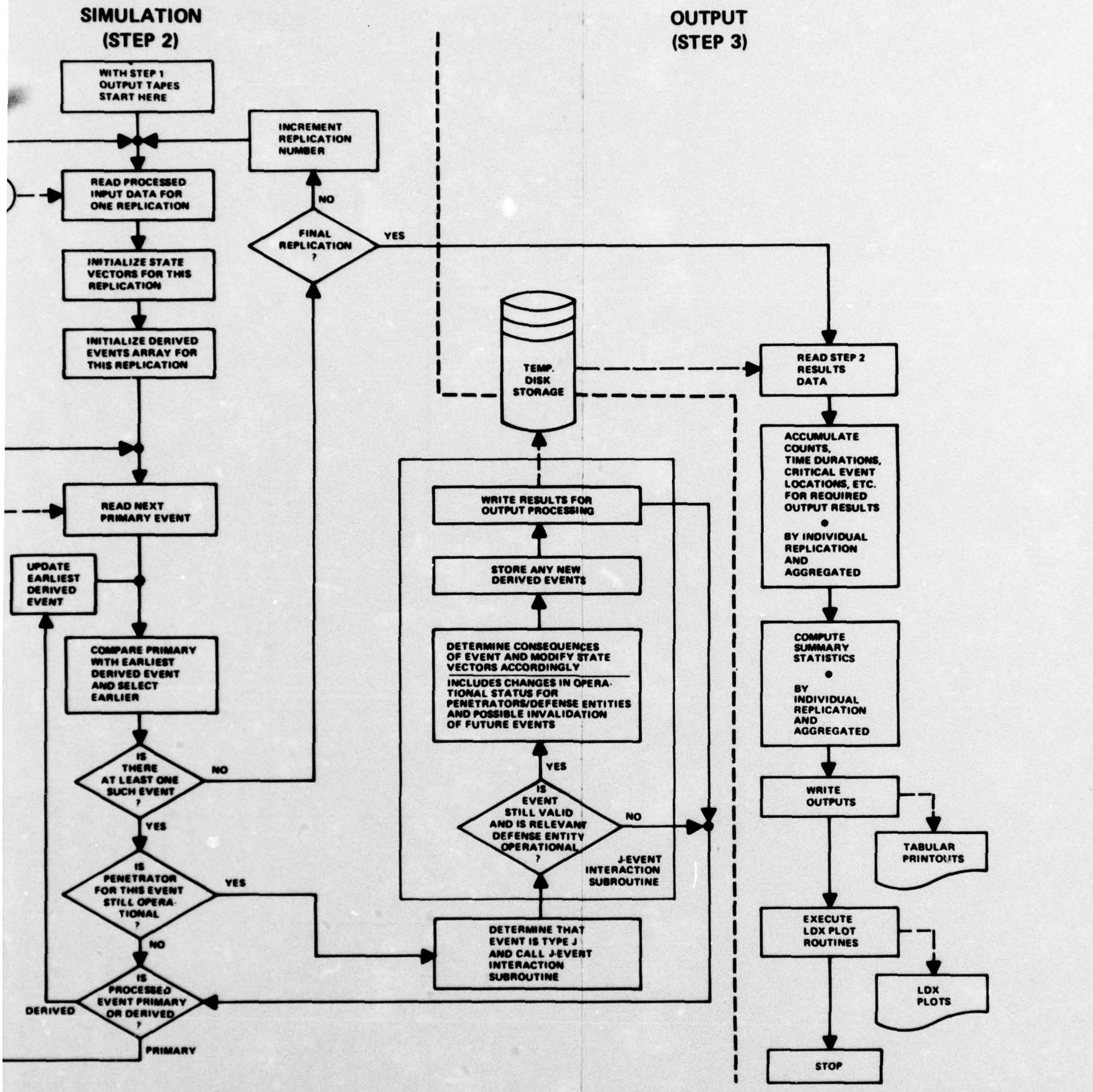


Figure 3 SPEED I MODEL FLOW DIAGRAM

2

2.2.1 Overall Simulation Flow

The Preprocessing and Primary Events Generation Step (Step 1) begins with data inputs (from punched cards and/or disk library) describing: penetrator flight paths, weapon target designations, air defense system composition, and interaction tables. Flight paths are perturbed or deleted, as previously discussed, and random terrain mask angles computed for use in defining visibility zones around EW and SAM sites. Inputs are also processed to meet the Simulation Step needs. Following this, primary events are generated for a given replication. It should be noted that because of the generally large number of combinations of interacting penetrators and EW & SAM sites, entry and exit event computations are often a major part of the Step 1 running time. For this reason much care was taken to develop a highly efficient procedure for computing visibility zone entries and exits. Finally, the primary events and processed data are outputted for use in subsequent steps. A magnetic tape record is also made of the processed data outputs (but not of the primary events - which are as yet unordered in time). This procedure is repeated for as many Step 1 replications as called for in the run design.

The primary events are fed into a System 370 Sort/Merge program which provides an event sequence output ordered by replication number and, within each replication, by event time. A magnetic tape record is also made of the ordered primary events.

The Simulation Step (Step 2) may follow directly from the above Sort step or it may be the first step of a separate run using the magnetic-tape-stored primary event and processed input data generated above. The rationale for this option is that Step 1 is the most expensive step and, where new runs represent only parametric variations of earlier runs that do not alter the primary events, the earlier computations should not have to be redone.

Step 2 sequences through the replications set up by Step 1. Within each replication, the processed input data are first read in and the state

vectors for penetrators and defense entities initialized. The following are the major components of penetrator and defense entity state vectors.

Penetrator*

- General status: e.g., inflight-unengaged, under AI engagement, killed by SAM type X, etc.
- State of ECM modules: off, on, or failed (per module)
- Index of engaging AI
- Index of controlling GCI
- Index of assigning ZOC
- Index of engaging SAM site
- Time of exit from visibility zone of controlling GCI

EW/GCI/AWACS Site

- Status: operational, destroyed
- Numbers of detected targets: clear detections, strobes, burnthroughs
- Numbers of reported targets: clear detections, strobes, burnthroughs

Subcontrol

- Numbers of current target reports: clear detections, strobes, burnthroughs
- Numbers of designated targets (established tracks): point targets, triangulated targets, strobe targets

ZOC

- Numbers of targets in track: point, triangulated, strobe
- Number of targets under AI engagement

---

* Stored flight paths make it unnecessary to include penetrator position as part of the state vector.

GCI/ACI

- Status: operational, destroyed
- Number of vectoring channels in use (targets toward which AI are being vectored)

AI

- Status: on CAP, on loiter, engaging penetrator, expended*
- Fuel remaining
- Last reported position and time
- Projected intercept position and time

Air base

- Status: operational, destroyed
- Remaining AI inventory (by type)

SAM site

- Status: operational and number of targets under active engagement, destroyed
- Remaining missile inventory

Penetrator - EW/GCI/AWACS site interaction

- Detection status: not detected, clear detection, strobe, burnthrough - & reported or unreported to subcontrol

Penetrator - Subcontrol interaction

- Number of point detection reports on penetrator at subcontrol

---

* AI may be "expended" either by having used up its AAM load or by reaching a point where it has only sufficient fuel to return to base.

- Number of strobe detection reports on penetrator at subcontrol
- Target track status: not a target, point target, triangulated target, strobe target

Penetrator - ZOC interaction

- Target track status: not a target, point target, triangulated target, strobe target
- Time of lost contact (for radars within each air defense zone)
- Time of penetrator turn following lost contact

Penetrator - GCI/ACI interaction

- Visibility of penetrator to each GCI/ACI

During the execution of Step 2, derived events (see paragraph 2.1.4) are generated, internally stored in a Derived Events Array, and processed along with the sequentially inputted primary events. The procedure followed by Step 2 is: to have read in at any moment the next, as yet unprocessed, primary event, to compare it with the earliest derived event in storage, select the earlier of the two to be processed, and call the interaction subroutine corresponding to that event type. There are, of course, provisions for bypassing the processing of an event when either the penetrator or defense entity (if any) involved is no longer operational.

The various event interaction subroutines will be summarized in paragraph 2.2.3. In general, they compute the significant (deterministic and random) consequences of the event in question, modify state vectors accordingly, generate and store new derived events, occasionally invalidate a future event (e.g., AI engagement completed) for which an updated version has just been introduced, and write selected results for output processing.

On return to the main Step 2 program, the cycle of earliest-event determination and processing is repeated until all events are exhausted. The program then sequences to the next replication and proceeds as above until all replications are completed.

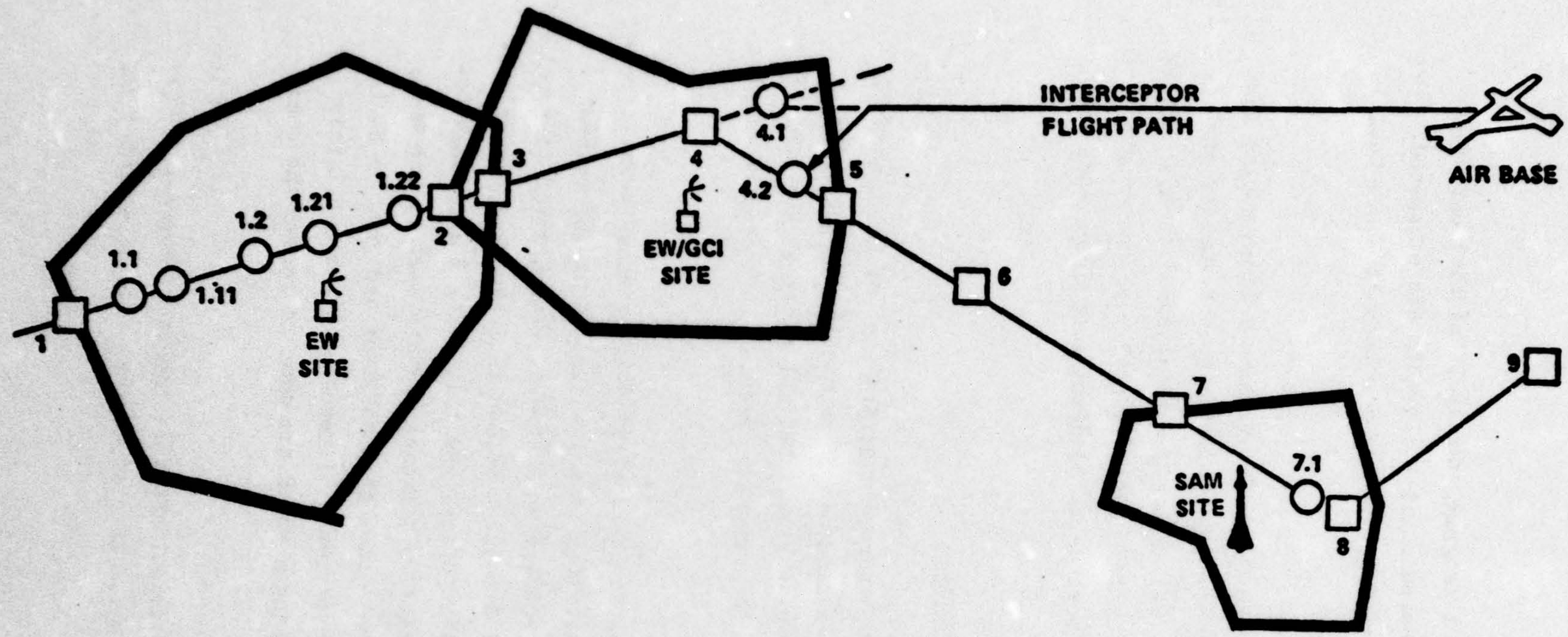
The final step (Step 3) accumulates the outputs written during the Simulation Step, aggregates them appropriately, and computes summary statistics for individual replication as well as for the total run. Tabular printouts and LDX plots are produced which correspond generally to the output listing noted in paragraph 2.2. A more detailed discussion of outputs will be provided in paragraph 2.5.

2.2.2 Illustrative Sequence of Events

In order to provide a more concrete understanding of how the SPEED Model operates, a short illustrative sequence of events for a single penetrator is presented in Figure 4 in plan view. Decimal notation for derived events signifies order in relation to primary or previously generated derived events.

Upon penetrator entry into an EW radar visibility zone (Event 1), the model establishes that the penetrator is noise jamming at the relevant radar bands and is immediately detectable as a strobe. Two derived (future) events are generated: 1.1, Initial Report of Strobe to Subcontrol (in accordance with a radar-load-dependent time delay) and 1.2, Radar Burnthrough Detection (based on achieving a critical S/J ratio). State vectors are modified to reflect change in detection status of penetrator and load on EW radar site. (In the interest of brevity we will henceforth not explicitly refer to many of the state vector changes which are made to record the consequences of events.)

The next event processed is 1.1 and this generates Event 1.11, Designation by Subcontrol, again based on a subcontrol load-dependent time



PRIMARY EVENTS

1. EW RADAR ZONE - ENTRY
2. EW/GCI RADAR ZONE - ENTRY
3. TURN POINT
5. EW/GCI RADAR ZONE - EXIT
6. ECM MODULE NO. 3 FAILURE
7. SAM SITE - ENTRY
8. FLIGHT PATH TERMINATION (INFLIGHT VEHICLE FAILURE)
9. PLANNED TERMINATION

DERIVED EVENTS

- 1.1 STROBE REPORT TO SUBCONTROL
- 1.11 DESIGNATION BY SUBCONTROL (TARGET TRACK NOT ESTABLISHED)
- 1.2 EW RADAR BURNTHROUGH
- 1.21 STROBE-TO-BRUNTHROUGH CHANGE REPORT TO SUBCONTROL
- 1.22 DESIGNATION BY SUBCONTROL (POINT TARGET TRACK ESTABLISHED; TRANSFERRED TO ZOC; AI ASSIGNED)
- 4.1 AI ENGAGEMENT COMPLETED
- 4.2 AI ENGAGEMENT COMPLETED
- 7.1 SAM ENGAGEMENT COMPLETED

Figure 4 ILLUSTRATIVE SEQUENCE OF EVENTS

delay. On the assumption that this is the only strobe report to that subcontrol, no target track is established, and no further derived event is generated.

Event 1.2 is next, generating 1.21, Strobe-to-Burnthrough Report Change to Subcontrol, which in turn generates 1.22, Designation by Subcontrol. The consequence of Event 1.22, in view of the burnthrough, is establishment of a point track, transfer of this track to ZOC, and finally after some further time delay, the assignment of an AI and controlling GCI to engage the penetrator. This results in generation of Event 4.1, AI Engagement Completed, computed to occur at the time and place of vectored course intercept.

An EW/GCI site visibility zone is next entered (Event 2) - assume this site to be the one vectoring the AI to intercept - and this triggers a series of events more or less like that of 1.1 - 1.11 - 1.2 - 1.21 - 1.22, which we disregard in this brief illustration. Meanwhile, Events 3 and 4, respectively, EW Radar Exit and Penetrator Turn, are processed. The latter causes an updating of AI intercept with generation of a new AI Engagement Completed Event (4.2) and invalidation of Event 4.1.

On processing of Event 4.2, it is determined by random number draws that (for example) the AI was successful in encountering the penetrator, i.e., it converted and fired its AAM, but that none of the individual missile shots resulted in penetrator kill. (These determinations take account of many factors, including type and altitude of penetrator, employment of ECM, type of AI, nature of target track, and use of dead-reckoning by GCI.)

The penetrator next proceeds to exit the EW/GCI radar visibility zone (Event 5), suffers a failure in one of its ECM modules (Event 6), and enters the visibility/missile capability zone of a SAM site (Event 7). In Event 7 a SAM Engagement Completed Event (7.1) is generated corresponding to the expected time of penetrator kill by a SAM missile given that the penetrator is killed. This event is reached next, and it is determined by a random number draw that the penetrator is indeed killed. The penetrator state

vector is changed accordingly and future events involving this penetrator (Events 8 and 9) are not processed.

To get some appreciation for the coordinated actions of netted EW sites, Subcontrols, GCI, and ZOC within the SPEED Model, the reader is referred to Figure 5. Here the effects of operator attention and information transfer time delays, strobe triangulation, target designation, AI assignment, dead-reckoning, and break-track unfold for a single penetrator during a portion of its flight. Note in this illustration that strobe reports at subcontrol establish a triangulated target track when there are three concurrent strobes. ZOC target track status on a given penetrator is set at the most definitive status among the individual subcontrols netted to that ZOC. AI/GCI assignments are made by ZOC on establishment of track or following unsuccessful engagement, assuming the track still exists. After a period of track extrapolation under lost contact, the track is deleted. In the present illustration, the two tracks, separated in time, are not necessarily recognized as coming from the same penetrator, especially if there had been an intervening penetrator turn. Following kill by the third AI, the penetrator is deleted from further simulation.

2.2.3 Major Event Interactions

The following paragraphs outline the more significant effects or interactions computed within each of the event type interaction subroutines. Checks on operational status of penetrator and defense entities, and state vector changes which accompany event processing are not specifically called out in most cases. For additional details the reader is referred to Volumes II and III of this report.

1) Penetrator Launch or Entry into Simulated Area

- Computations for this event are generally of the nature of state vector changes, e.g., penetrator status set "to in-flight, unengaged" (or "failed-at-launch," if so predeter-

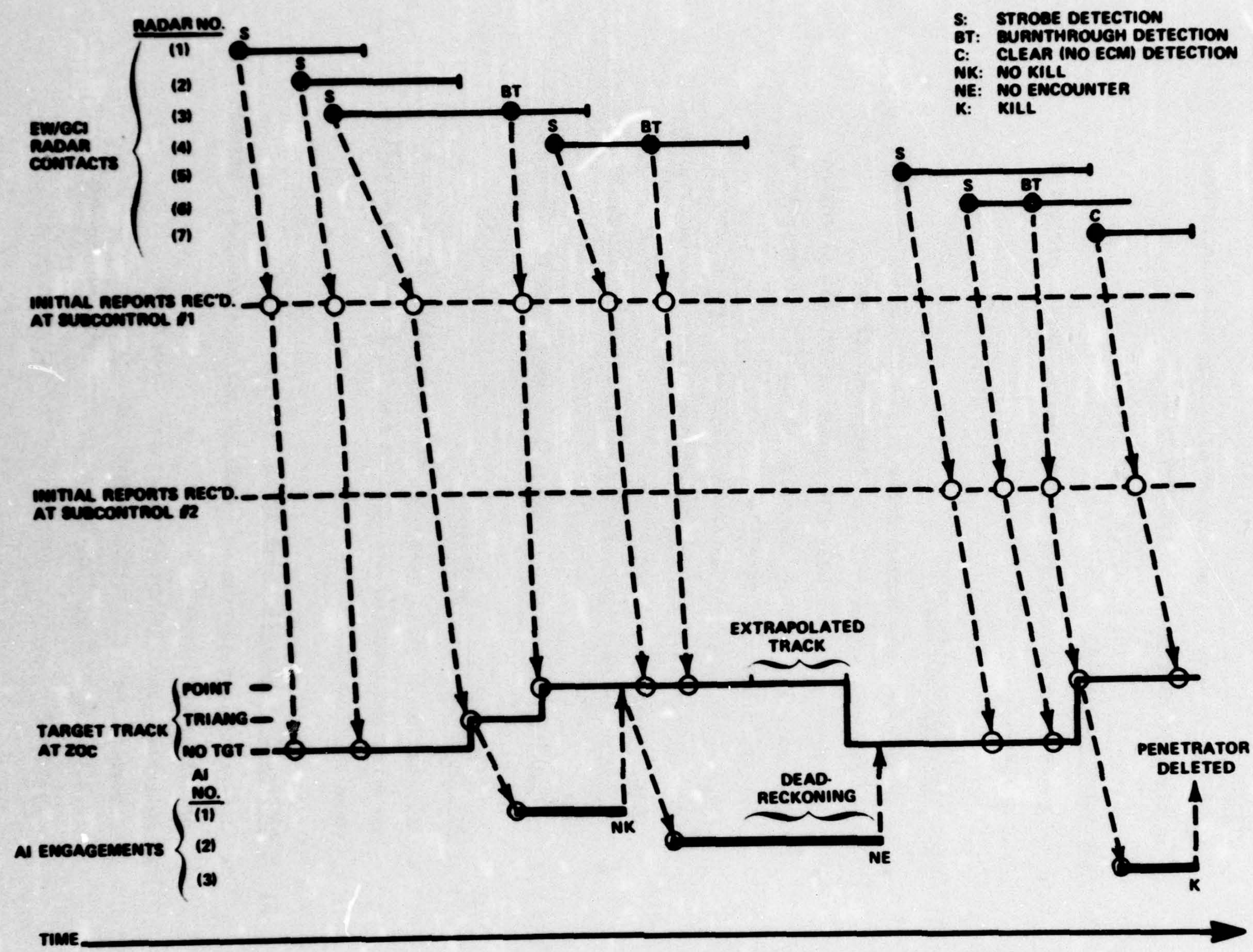


Figure 5 ILLUSTRATIVE COMMAND & CONTROL COORDINATION (FOR SINGLE PENETRATOR)

mined during Step 1), and number of unlaunched penetrators in aircraft of given type reduced by 1.

2) Penetrator Turn Point

- If under radar contact and AI engagement, update projected AI intercept.

3) Penetrator Terminal Point

- If event represents weapon delivery, determine EW/GCI/AWACS site, airbase, and/or SAM site destroyed (if any)
- If destroyed site includes GCI center, abort all AI engagements under its control; reassign AI and GCI against "freed" penetrators wherever possible.
- If destroyed entity is an AWACS, abort all AI engagements under its control; if any "freed" penetrators are under ground track, attempt new assignments.
- If Airbase is destroyed, remaining ground AI inventory is lost.
- If SAM site is destroyed, abort all engagements in progress.

4) Change in Penetrator ECM Status

- This causes a simple state vector change which is relevant to detection computations made in the EW/GCI/AWACS visibility zone entry event.

5) EW/GCI/AWACS Visibility Zone-Entry

- Determine if detection is immediate and whether clear, strobe, or strobe-burnthrough.
- Determine possible future clear detection event.
- Determine possible future burnthrough event.
- If site has EW function, determine future report to subcontrol event.

- If AWACS, determine possible direct AI assignment and consequent AI engagement completed event.
- If radar contact has been re-established following an unobserved penetrator turn (course change) and penetrator is under AI engagement, update projected AI intercept.

6) EW/GCI/AWACS Visibility Zone-Exit

- Computations for this event are generally of the nature of state vector changes; e.g., if penetrator is under AI engagement and controlling GCI has just lost coverage, then handover to another GCI is attempted but, if not possible, time of lost GCI contact (start of dead-reckoning) is noted.

7) SAM Site Visibility & Capability Zone-Entry

- If site is not saturated or depleted of missiles, then, taking into account appropriate delays and ECM effects, determine: maximum possible number of missile salvos fired (if any), associated total engagement probability of kill, associated expected number of missiles fired, and expected time of penetrator kill, given kill. The last is used to establish a future SAM engagement completed event.

8) Delayed Clear Detection by EW/GCI/AWACS Site

- Essentially the same as 5 above.

9) Delayed Strobe Burnthrough by EW/GCI/AWACS Site

- If site has EW function, determine future strobe-to-burnthrough detection report to subcontrol.

10) Initial Detection Report to Subcontrol

- Compute time delay at subcontrol and accordingly determine future target designation event.

11) Strobe-to-Burnthrough Detection Report to Subcontrol

- Essentially the same as 10 above.

12) Target Designation

- Determine if triggering report implies the initiation of a target track at subcontrol and transfer to ZOC (or upgrading of an existing track, e.g., from triangulated track to point track).
- If new or upgraded track, and penetrator is not currently under AI engagement, attempt to assign AI and controlling GCI. If assignment possible, record projected intercept point and establish a future AI engagement completed event.
- If assignment not currently possible, establish a future AI assignment reassessment event.

13) Assignment Reassessment

- Test for possible break-track by this ZOC.
- If track continued and currently not under AI engagement, attempt to assign AI and controlling GCI. If assignment possible, record projected intercept point and establish a future AI engagement completed event.
- If assignment not currently possible, establish a future AI assignment reassessment event.

14) AI Engagement Completed

- If AI on strobe-following intercept, test AI fuel and abort if insufficient.
- Determine by random number draw if AI encounters penetrator (probability of encounter is influenced by: penetrator type, altitude, ECM, interceptor type, ACI or GCI, point or strobe-target vectoring, and extent of terminal dead-reckoning).

- If successful encounter, determine by random number draw if an AAM fired by AI kills penetrator.
- If no encounter or no kill, test for possible break-track by ZOC.
- If track continued, either attempt an immediate new AI/GCI assignment or establish a future AI assignment reassessment event.

15) <u>SAM Engagement Completed</u>

- Determine by random number draw if a SAM kills penetrator (probability of kill was computed during SAM entry event).

2.2.4 Assumptions and Implicit Doctrine

In previous sections various idealizations, assumptions, and doctrinal choices made in developing the SPEED model structure have been identified. In this section these factors are described in more detail to provide explicit information as to the applicability and limitations of the SPEED model.

Penetration and Defense Suppression

- Flight paths: preplanned, uniform-velocity straight-line segments (no turn radii, no extended reactive maneuvers).
- ECM: preplanned, modularized barrage noise jamming (and optional cross section augmentation); ERP pre-adjustable vs each defense radar type.
- Radar cross section: by frequency band and (five) azimuthal sectors.
- For one penetrator class: constant failure rates for each of various type (launch, inflight, and ECM module) failures.
- For one penetrator class: navigation error CEP proportional to range; and direction of error uniformly distributed, but fixed for each penetrator.

- For one penetrator class: fuel consumption rate specified by speed, altitude, and remaining fuel.
- Defense suppression modeled by lethality circle (as a function of weapon and target) centered at DGZ, i.e., no damage outside circle and assured destruction inside circle. It is assumed that any subcontrol or ZOC suppression would be counteracted by use of redundant back-up sites.

Detection and Early Warning

- Terrain masking: random mask angle for each of eight principal directions drawn from uniform distribution between zero and maximum mask angle. Latter is site dependent. Visibility between principal directions by linear interpolation. Obstructing terrain is assumed to be always between target and radar.
- Detection range: deterministic detection at S/N corresponding to 50 percent single-scan probability of detection. If jamming is present within any of the site's radar bands, then strobe detection occurs on condition of visibility. Point detection is based on the radar at site with highest performance for the given situation.
- Average time delay for initial detection report to subcontrol is dependent on nature of detection and instantaneous target load at radar. At high loads penetrator target may be completely missed by the time penetrator exits radar visibility zone.
- AWACS are assumed located at an artificial stationary point rather than on an orbit. The radar is assumed not to be clutter-limited. Handover and other cooperative interactions with the ground-based air defense system are modeled to only a limited degree.

Target Designation, Discrimination, and Air Defense Assignment

- Any single clear or burnthrough target detection report on a penetrator is sufficient to initiate a target track at subcontrol.
- Three or more strobe reports concurrently received at subcontrol on a given penetrator permit subcontrol to infer a triangulated target track.
- Decoys are assumed 100 percent credible, i.e., there is currently no provision for classification of target track by the defense according to apparent penetrator class nor any logic built in for differential defense response.
- Average time delay for filtering of radar returns and target designation at subcontrol, and track transfer to ZOC, is dependent on nature of subject target report and report load at subcontrol.
- ZOC makes AI assignment based on the criterion of earliest possible intercept time. Intercept times are computed by a collision course model (plus a fixed initial time delay, and in the case of strobe-following interceptions a fixed percentage penalty). An additional requirement is that there must be a GCI center with open vectoring channel within nominal (altitude-dependent) radar visibility range of the predicted intercept point.
- A proportion of AI inventory at each base is initially airborne (on CAP), assignments select from these AI, and the CAP slots are continually replenished until ground inventory depletion.
- A penetrator will not be engaged by two or more AI simultaneously.
- Although SAM sites should be realistically viewed as under the FCC, and ultimately, ZOC control, it is assumed because of the generally localized nature of penetrator - SAM interaction that penetrator entry into the combined zone of tracking radar visibility and missile range capability will generally trigger an attempted SAM response (unless site is saturated or depleted of missiles).

- AWACS can initiate its own AI assignments, using accompanying CAP presumably under ZOC coordination, but still circumventing much of the C&C delay associated with ground-based early warning. It requests replenishment from a dedicated air base inventory as soon as an assignment is made.
- If contact with tracked penetrator is lost by all sites netted to a given ZOC, then track is maintained by extrapolation for a fixed period of time before being expunged.
- Target track maintenance at a ZOC is assumed to be independent of status at other ZOCs.

AI Engagement

- If a penetrator being engaged by an AI makes an observed turn, then a new predicted intercept point is computed and the AI flight adjusted accordingly. If the result of the turn makes interception impossible (e.g., intercept would have to occur out of visible range to any GCI center) then the intercept is aborted and the AI is loitered at its last position.
- The end game is represented by a sequence of two steps: (1) the terminal search, detection, lock-on, and conversion into firing position; and (2) the firing of AAM. (This sequence could typically be repeated a second time.) Under detailed consideration of AI end game doctrine and tactics for various AI types and intercept altitudes, it is possible to establish two probabilities: (1) a probability of AI successful encounter, i.e., probability that the AI will fire at least one AAM, and (2) a conditional probability of kill given encounter. These two probabilities are in turn relatable to more fundamental quantities, such as: probability of being successfully vectored to within detection range, probability of conversion for frontal attack, probability of conversion for rear attack, and AAM single-shot probability of kill. In summary, then, the consequence of AI intercept is determined by comparison of random draws with two input probabil-

ities selected in accordance with the specific conditions of the intercept.

- Strobe-following AI intercept assignments are made without any fuel test. Consequently, such an intercept may at times be aborted when the AI reaches its "point of no return" for getting back to base.
- AI returning to base are not recycled within the current version of SPEED.

SAM Engagement

- SAM and AI engagements of a given penetrator may overlap - and it is assumed that there are no interfering effects.
- The maximum number of missile shots is estimated from consideration of: time within visibility/missile capability zone (excluding dead-zone), missile salvo fly-out time (including intersalvo delay), missiles per salvo, and track initiation time. Input tables supply the probability of successful track initiation and the single-shot probability of kill in accordance with the specific conditions of the engagement. The consequence of the SAM engagement is then determined, from a single random draw, as either penetrator killed or penetrator not killed. Site missile inventory is in any event reduced by expected number of expended missiles.

2.3 SPEED I PROGRAM STRUCTURE

As presently configured for the IBM System 370/165 at Calspan's Computer Center, SPEED utilizes nine program execution steps in various combinations, identified as:

INPUT
STEP 1
TAPE 1

SØRT
TAPE 2
DUP
STEP 2
STEP 3
PLØTS

(Four of these steps have already been noted in the paragraph 2.2.1, Discussion of Overall Model Flow.)

INPUT

The basic function of INPUT is to select data sets from permanent disk storage (DISK LIBRARIAN), make changes - either permanent or temporary for the given run, introduce additional data as required via punched cards (e.g., random number seed, number of replications, and run label), and thereby create a complete input data set for STEP 1. Time and core storage utilization by INPUT is relatively insignificant.

STEP 1 (Preprocessing)

As described in paragraph 2.2.1, STEP 1 generates the replicated primary events and processed data inputs for STEP 2. Core requirement is approximately 300 K bytes and running (CPU) time per replication has ranged from 5 to 30 seconds for the cases treated to date.

TAPE 1

This is a minor step which generates a permanent tape file of the processed data sets out of STEP 1, when such is required for parametric variations.

SØRT

As previously described, SØRT applies a System 370 Sort/Merge program to order the primary events by replication number and by time within each replication. Core requirement is modest at a little over 100 K bytes, with CPU time in the vicinity of .25 to .5 second per replication.

TAPE 2

This is a minor step which generates a permanent tape file of the ordered primary events data set out of SØRT, when such is required for parametric variations.

DUP

DUP creates a specified number of carbon copies (duplicates) of all, or any selected subset of, STEP 1 output replicates. The rationale for this procedure is that because random effects occur in both STEP 1 and STEP 2, with the former more expensive to run, the variance of output measures may be minimized (under a total running time constraint) by use of fewer STEP 1 replicates each of which is passed through STEP 2 several times. About 350 K bytes of core are used and CPU time is roughly 2 seconds per output duplicate.

STEP 2

As described in paragraph 2.2.1, STEP 2 is the main simulation step - it processes all primary and derived events in sequence and accumulates data on output measures. Again, about 350 K bytes of core are used and our experience with respect to runs processed to date has been that from 2 to 7 seconds of (CPU) running time is expended per cycle (i.e., for each duplicated replicate).

STEP 3

This step conducts the necessary output data processing, including statistical mean and standard deviation calculations. It also sets up the proper data set for automatic (LDX) plotting. Core storage is 200 K bytes and prorated CPU time is in the vicinity of 0.5 second per cycle.

PLØTS

This step is a standard software package which sorts the plot data and feeds the LDX plotter for generation of the desired output graphs. Time and core storage utilizations by PLØTS are relatively insignificant.

2.4 INPUT DATA

Inputs to the SPEED I Model may be divided into three functionally distinct portions: (1) a small number of job option controls, print controls, random number generator seeds, etc. which are presented in card form at the beginning of a run; (2) the bulk of the data, which are categorized into sixteen data sets and typically are pre-stored in a disk library; and (3) some data which are built into subroutines or function subprograms. The latter two portions of the input data are discussed below, followed by a description of the uses of various input data types within *SPEED I*.

2.4.1 Data Set Classification and Elements

Except where specifically noted, distances are in meters, velocities in m/s, times in seconds, and weights in lbs. All geographic locations are *inputted as latitude-longitude*, but are transformed early to X-Y projections on a tangent plane with Y axis oriented North and X axis East. The tangent point is provided with the aforementioned control inputs.

Data Set 1 - EW/GCI/AWACS Radar Sites

Entry for each site (numbered consecutively) contains the following information:

- Location.
- Radar complement - provides for up to five radars of different type; current provisions permit selection from among 20 radar types.
- Function - distinguishes among EW only, EW/GCI, GCI only, and AWACS.
- Associated GCI/ACI center number - GCI/ACI centers are separately, consecutively numbered. When association is from EW site to GCI, it means that EW site can effectively extend coverage of that GCI center.
- Number of subcontrol to which site is netted.
- Altitude - currently used for AWACS only.
- Maximum mask angle - in radians.
- No-mask index for each of eight principal directions - indicates which directions (if any) are known to have an unmasked view, like at a seacoast location. This index thus permits maximum mask angle to be ignored for selected directions.

Data Set 2 - Radar Type

Entry for each radar type contains the following information:

- Associated decoy ECM module number - also implies radar band or group of bands.
- Maximum (PRF-limited) range, in n.mi.
- Minimum permissible elevation angle. (Note that detection and burnthrough ranges are contained in Data Set 11.)

Data Set 3 - Subcontrol Centers

This specifies, for each subcontrol, the zone operations center (ZOC) to which the subcontrol is netted.

Data Set 4 - Zone Operations Center (ZOC) Characteristics

- Maximum permissible gaps in radar contact for track continuity
  (a) with no intervening penetrator turn,
  (b) following an intervening penetrator turn.
- Delays from establishment of target track on penetrator to start of AI engagement (i.e., assignment of GCI and interceptor made, and interceptor on its way)
  (a) under GCI control,
  (b) under AWACS/ACI control.
- Degrade factors in probability of penetrator encounter by vectored AI for engagements under
  (a) AWACS control*,
  (b) strobe-following control*.

Data Set 5 - Air Bases**

Entry for each base contains the following information:

- Location.
- ZOC (possibly more than one) to which base is netted.
- Initial interceptor inventory by AI type - on ground and on CAP.

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* Logically, these characteristics belong with Data Set 16.

** Includes bases which function strictly as AWACS CAP replenishment facilities (may coincide with other air bases). The numbering system distinguishes these special bases.

Data Set 6 - Interceptor Types

- Time constants τ_1 and τ_2 of exponential degradation in probability of encounter under dead-reckoning. [Degradation factor is $\exp(-t_1/\tau_1 - t_2/\tau_2)$ where t_1 is duration of terminal dead-reckoned vectoring and t_2 is duration of terminal dead-reckoned vectoring following unobserved penetrator turn.]*

Entry for each interceptor type contains the following information:

- Scramble delay.
- Combat radius.
- Rate of climb.
- Cruise speed.
- Fuel consumption, climb.
- Fuel consumption, cruise.
- Fuel consumption, loiter/CAP.
- Maximum altitude.
- Minimum altitude.

Data Set 7 - GCI/ACI Centers

- Number of simultaneous vectoring channels available, as a function of GCI/ACI type.
- Time delay before reassigning interceptor after penetrator is not encountered
  (a) assuming point vectoring,
  (b) assuming strobe-following vectoring.

* Logically, these characteristics belong with Data Set 16.

Entry for each GCI/ACI center contains:

- Number of EW/GCI site with which center is colocated.
- ZOC (possibly more than one) to which center is netted.

Data Set 8 - SAM Sites

Entry for each SAM site contains:

- Location.
- Type identification - provision for up to eight types.
- Maximum mask angle - in radians.
- No-mask index for each of eight principal directions (cf. Data Set 1).

Data Set 9 - SAM Types

Entry for each SAM type contains the following information:

- Identification of target tracking radar (TTR) type (as per Data Set 2).
- Minimum time delay from initial detection by TTR to first possible missile launch.
- Number of targets that can be simultaneously engaged.
- Initial missile inventory assumed for all sites of given type.
- Salvo flyout time to maximum range interception.
- Number of missiles per salvo.
- Maximum interception range (missile/guidance limited).
- Minimum interception range (radius of dead zone).
- ECM degrade factor - associated with initiation and maintenance of track.
- Aggregated probability of track initiation/maintenance, by penetrator type and altitude regime.

- Aggregated single shot probability of kill given launch, by penetrator type and altitude regime.

Data Set 10 - DGZs

Entry for each DGZ contains the following information:

- Location.
- Identification numbers of EW/GCI sites, air bases, and/or SAM sites (if any) at DGZ or colaterally located within a specified radius.

Data Set 11 - Detection and Burnthrough Range Table

This table contains aggregated clear detection and burnthrough ranges of each of the radar types introduced in Data Set 2 vs each penetrator type with specified ECM configuration* for five separate azimuth angle aspect intervals. The criterion used in calculation was 50 percent single-scan probability of detection. Azimuth angle intervals were selected to best represent major changes in magnitude.

Data Set 12 - Bomber Flight Paths and Launches

Entry for each bomber contains the following information:

- Number of check points in bomber flight path (a check point can represent a trajectory turn, initiation or termination of altitude change, or a weapon/decoy release point).

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* Effective radiated power densities as well as antenna gain patterns were taken into account. Decoy in cross section augmented and unaugmented modes appear as distinct penetrator types in the table.

- Number of planned launches.
- Group or wave number, if any.
- ECM indicator - currently used in "all ECM on" mode only.
- For each check point: location, time*, altitude, speed, from this check point to next.
- For each planned launch: vehicle type (4 types currently possible, including decoys), bomber check point at which vehicle is launched, DGZ number of target (if any).

<u>Data Set 13 - Decoy Data**</u>

- Probability of launch failure.
- Mean time between failures (MTBF) for air vehicle failures.
- MTBFs for failures in each decoy module.
- Navigation/guidance system positional error coefficient - currently CEP as a fraction of cumulative range flown.
- Initial off/on condition for each ECM module.

Entry for each decoy vehicle contains the following information:

- Identification of launching parent, targeted DGZ (if any), gross weight (lbs), decoy configuration designation, initial fuel (lbs), and number of check points in decoy flight path.
- At each check point of the nominal (i.e., error-free) decoy flight path: location, time*, altitude, speed from this check point to the next.

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* Times beyond the first check point are redundant with speed and are used only as a partial check on accuracy of mission flight path planning.

** Excluding fuel rates which are in next data set.

Data Set 14 - SCAD Fuel Rate Table

This table contains averaged SCAD fuel consumption rates, in lbs/sec, for various combinations of SCAD speed, altitude, and gross weight (from full load to fuel out). Additional tables provide for design variants, e.g., armed SCAD.

Data Set 15 - Weapon Data

- Delay-to-function-time (from launch).
- Fratricide radii of weapons vs penetrators*.
- Fratricide active times of weapons vs penetrators*.
- As an alternate to delay-to-function-time, the average speed of weapon along an assumed straight line trajectory from launch to DGZ.

Data Set 16 - AI Effectiveness Data

This data set contains tables of basic aggregated probabilities of encounter, and aggregated probabilities of kill given encounter, by airborne interceptors of different type vs penetrators of different types at low and at high altitudes. It should be recalled that probability of encounter may be degraded by factors associated with AWACS control or strobe-following (see Data Set 4) or with dead-reckoning time (see Data Set 6).

2.4.2 Inputs Within Subroutines or Function Subprograms

Data are used at several points in the SPEED I model which are effectively inputs, but which either were built into the program logic itself, or were input by means of function subprograms. These are not immutable

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* Model assumes fratricide if penetrator is within radius during any portion of the active time.

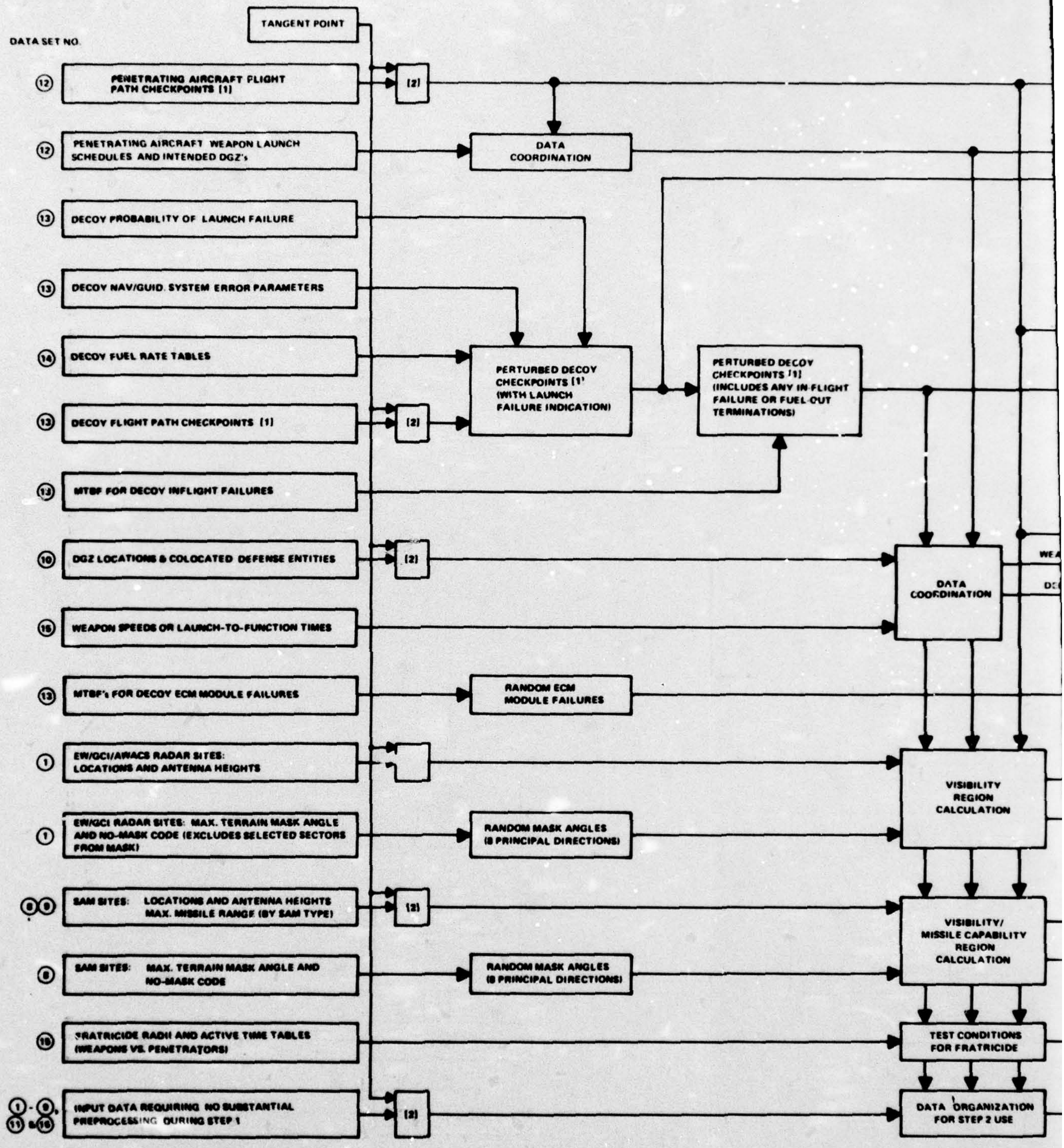
features; in fact any of these might appear as explicit inputs in future versions of the SPEED model. The items include:

- Time delay between detection at the radar site and receipt of the corresponding report at the subcontrol; this is a function of workload at the site and type of target (strobe, burnthrough, clear).
- Time delay between receipt of a report at the subcontrol and receipt of a target track at the zone operations center; this is a function of workload at the subcontrol and the type of report (strobe, burnthrough, clear).
- Nominal coverage range of GCIs as a function of penetrator altitude. A GCI must be found within nominal range of the projected intercept point before interceptor assignment can be made.
- Loiter/CAP altitude (and, implicitly, cruise altitude for low altitude intercepts. Note that the model does not explicitly fly interceptor flight paths). Currently, a single altitude is used for all loitering and CAP interceptors, regardless of type.

2.4.3 Uses of Specific Inputs in the SPEED I Model

Figures 6 and 7 depict functions performed within Step 1 and Step 2, respectively, of the SPEED I Model, and some of the interrelationships among those functions. At the left of each of these diagrams, the list of input items is given, and the relationship of each to the various functions within the model is indicated. The result is a simplified representation of the contribution of each specific input item to the functioning of the model.

Each function of Step 2 is linked to functions not represented here which produce SPEED I outputs. The intricacies of output production are beyond the scope of this summary report, and hence these diagrams make no explicit reference to output functions or the details of Step 3 of the model. The outputs themselves are described in paragraph 2.5.



(1) FLIGHT PATH CHECKPOINT DATA INCLUDE: TIME, LOCATION, CUMULATIVE DISTANCE FLOWN, SPEED, AND VELOCITY COMPONENTS AT EACH CHECKPOINT. FULL-REMAINING DATA ARE EVENTUALLY ADDED TO DECOY CHECKPOINTS.

(2) TRANSFORMATION OF ALL LOCATION DATA FROM LATITUDE/LONGITUDE TO CARTESIAN COORDINATES

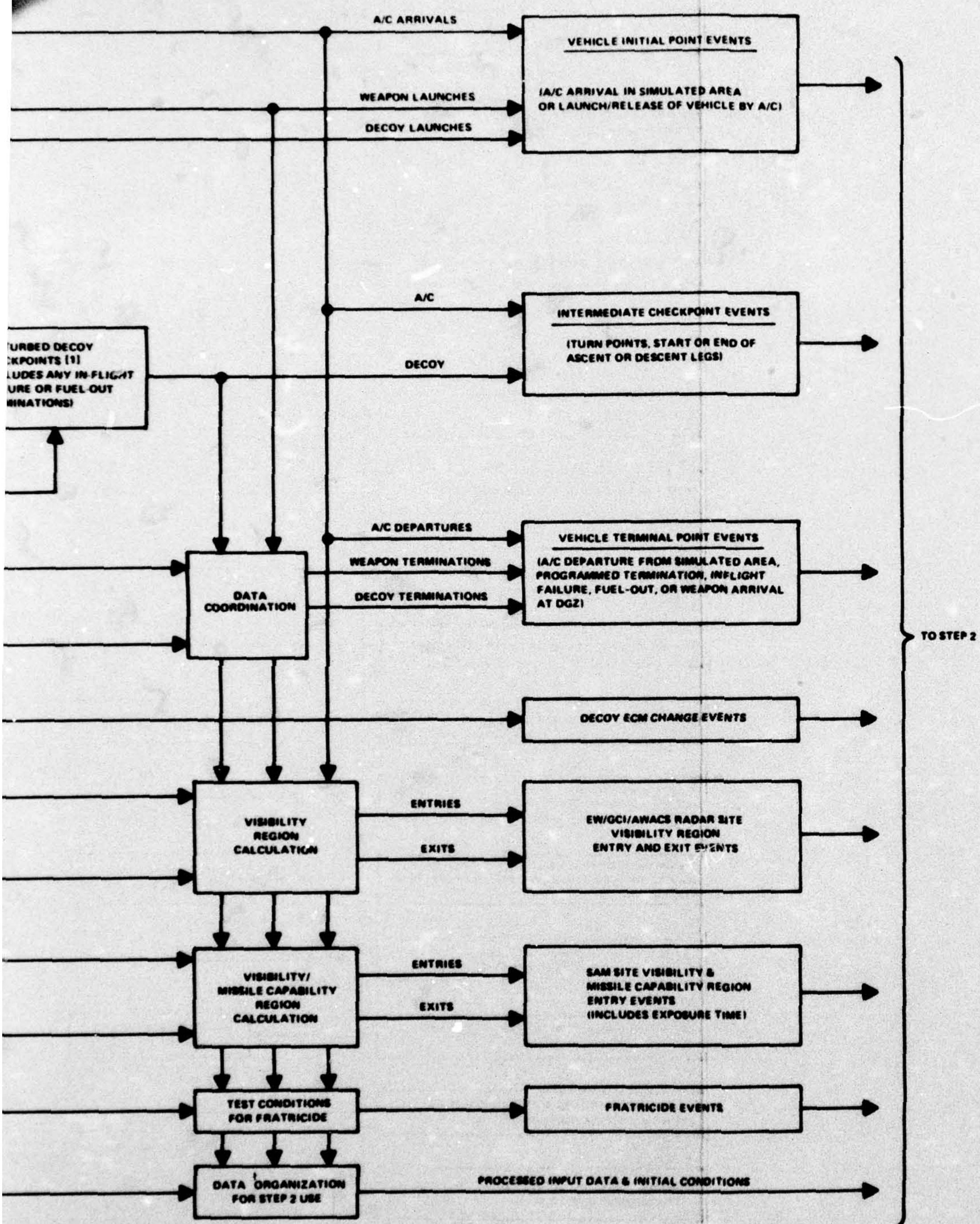
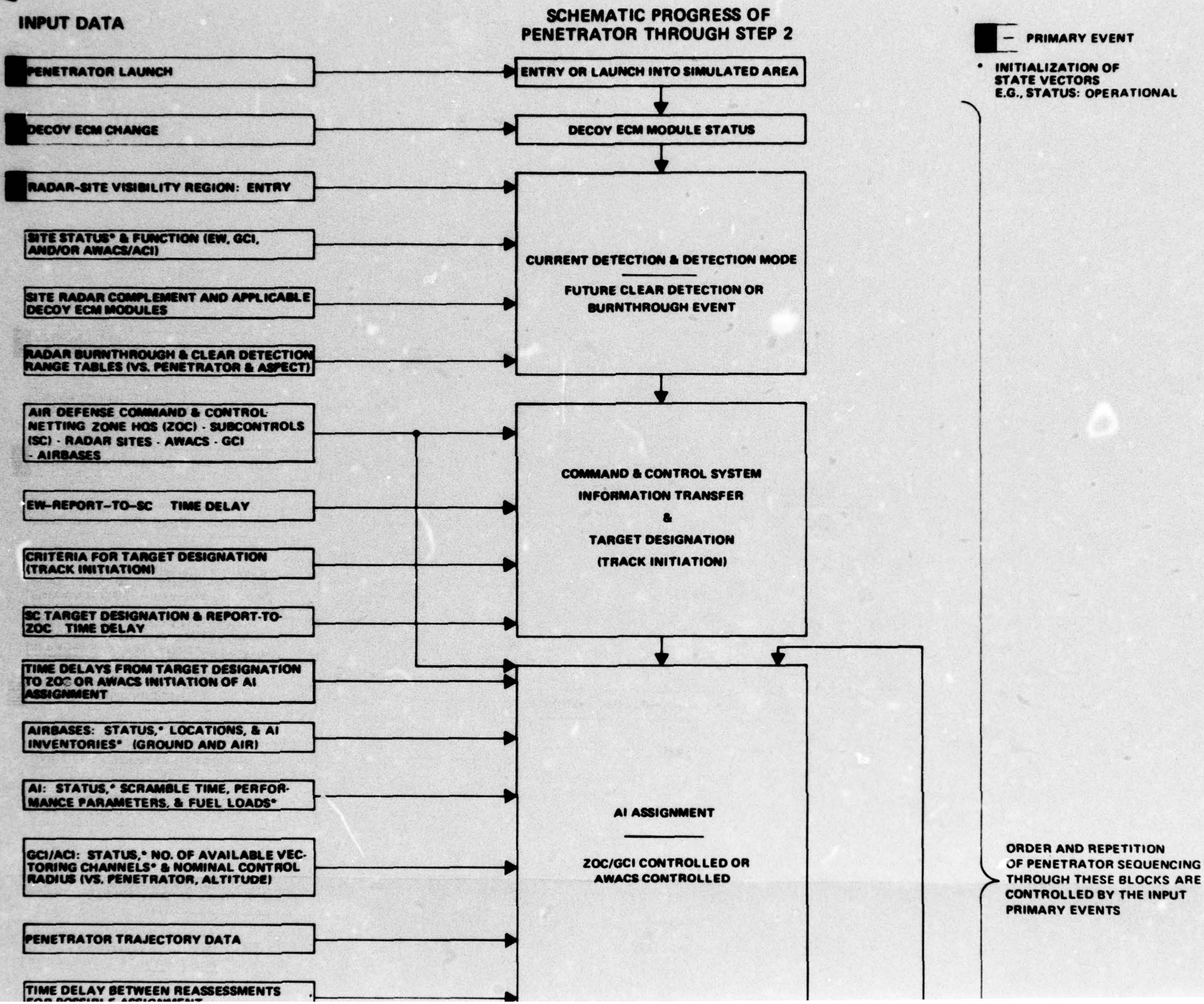


Figure 6 SPEED I MODEL—STEP 1 INPUT DATA UTILIZATION

2


INPUT DATA
SCHEMATIC PROGRESS OF PENETRATOR THROUGH STEP 2
PRIMARY EVENT
• INITIALIZATION OF STATE VECTORS E.G., STATUS: OPERATIONAL
PENETRATOR LAUNCH
DECOY ECM CHANGE
RADAR-SITE VISIBILITY REGION: ENTRY
SITE STATUS* & FUNCTION (EW, GCI, AND/OR AWACS/ACI)
SITE RADAR COMPLEMENT AND APPLICABLE DECOY ECM MODULES
RADAR BURNTHROUGH & CLEAR DETECTION RANGE TABLES (VS. PENETRATOR & ASPECT)
AIR DEFENSE COMMAND & CONTROL NETTING ZONE HQS (ZOC) - SUBCONTROLS (SC) - RADAR SITES - AWACS - GCI - AIRBASES
EW–REPORT–TO–SC TIME DELAY
CRITERIA FOR TARGET DESIGNATION (TRACK INITIATION)
SC TARGET DESIGNATION & REPORT-TO-ZOC TIME DELAY
TIME DELAYS FROM TARGET DESIGNATION TO ZOC OR AWACS INITIATION OF AI ASSIGNMENT
AIRBASES: STATUS,* LOCATIONS, & AI INVENTORIES* (GROUND AND AIR)
AI: STATUS,* SCRAMBLE TIME, PERFORMANCE PARAMETERS, & FUEL LOADS*
GCI/ACI: STATUS,* NO. OF AVAILABLE VECTORING CHANNELS* & NOMINAL CONTROL RADIUS (VS. PENETRATOR, ALTITUDE)
PENETRATOR TRAJECTORY DATA
TIME DELAY BETWEEN REASSESSMENTS
ENTRY OR LAUNCH INTO SIMULATED AREA
DECOY ECM MODULE STATUS
CURRENT DETECTION & DETECTION MODE
FUTURE CLEAR DETECTION OR BURNTHROUGH EVENT
COMMAND & CONTROL SYSTEM INFORMATION TRANSFER & TARGET DESIGNATION (TRACK INITIATION)
AI ASSIGNMENT
ZOC/GCI CONTROLLED OR AWACS CONTROLLED
ORDER AND REPETITION OF PENETRATOR SEQUENCING THROUGH THESE BLOCKS ARE CONTROLLED BY THE INPUT PRIMARY EVENTS

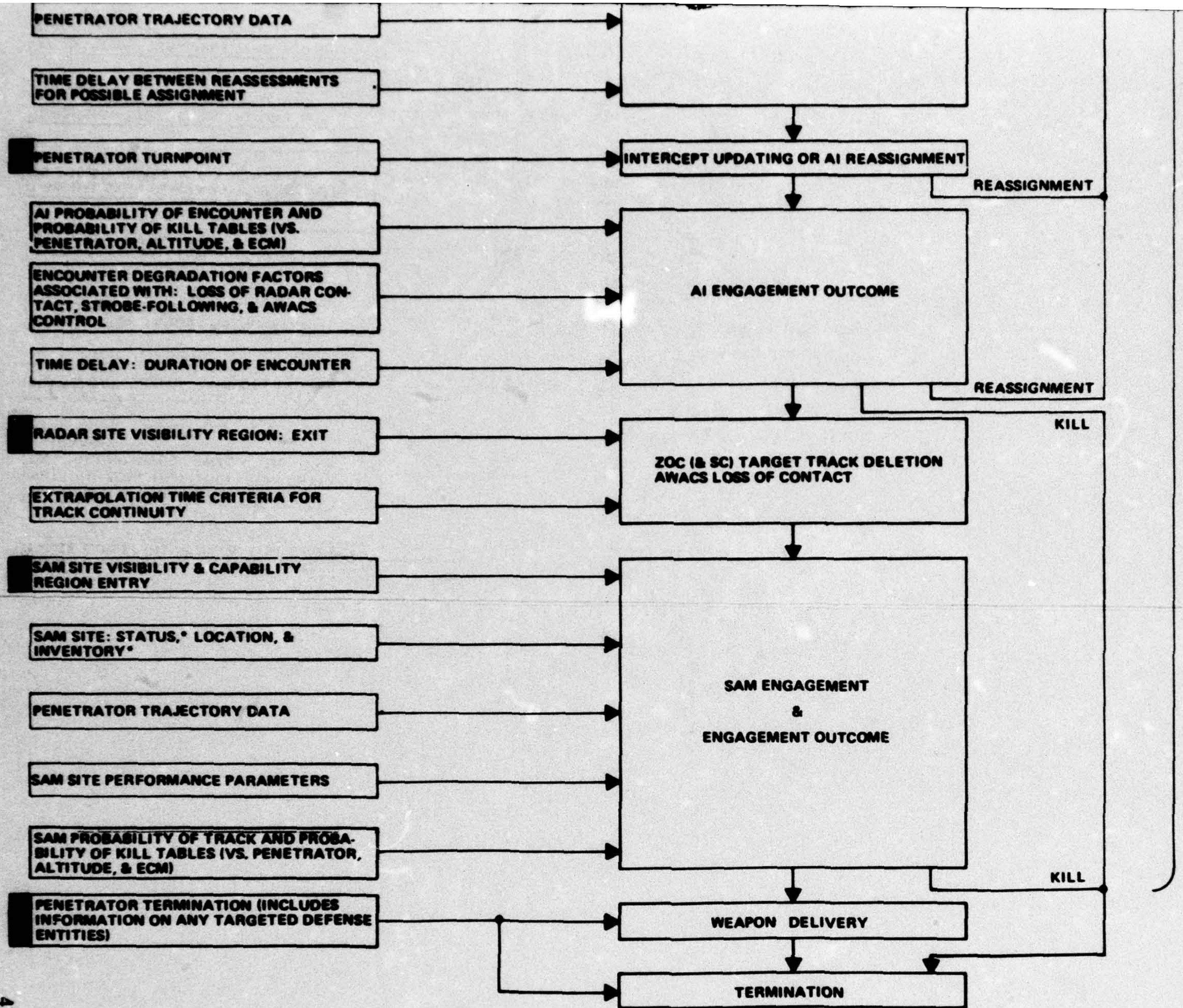


Figure 7 SPEED I MODEL – STEP 2 INPUT DATA UTILIZATION

2

Figure 6 emphasizes the major functions of Step 1, Preprocessing and Primary Events Generation. These are:

- Conversion of all location data to Cartesian coordinates.
- Perturbation of decoy flight paths to simulate navigational errors.
- Monte Carlo determination of mask angles surrounding EW and SAM sites to simulate terrain effects.
- Monte Carlo determination of decoy launch failures, in-flight failures and ECM module failures.
- Calculation of cumulative fuel consumption at each check point of the decoy flight paths.
- Calculation of penetrator fratricides.
- Provision of the primary events listed in paragraph 2.1.4.
- Reformatting (wherever necessary) and transfer of input data, not otherwise required in Step 1, to the simulation step. (Includes performing the transformation to Cartesian coordinates in the case of all location data.)

The right hand end of the figure gives the various Primary Event types generated for use in Step 2. It will be remembered from Figure 3 that the primary events are passed to STEP 2 as one data set either on magnetic tape or disk, while the remainder of the data are similarly passed as a second data set.

Using Figure 6, a specific Primary Event type passed to Step 2 can be traced backwards to find the input data used in generating events of that type. For example, the event marking the launch of a decoy is based on the set of perturbed decoy check points (with launch failures indicated) which depends in part upon the probability of launch failure and the time of the first check point of the decoy flight path. As with all location data, the launch event location makes use of the target point through the transformation from latitude and longitude to Cartesian coordinates.

The descriptive titles appearing at the left of Figure 6 in some cases are not individual items of data but represent several data items which are related in application within the model. To the left of each box, the data set number, as defined in paragraph 2.4.1, which contains the items in the box is given.

Figure 7 is a similar diagram relating input data items to the functions performed in the simulation step. In this case, the primary events generated in Step 1 are included along with the other data, both to emphasize their crucial role in SPEED I operation and to illustrate the relationship with Step 1 functioning. The functions depicted are for a typical penetrator, which in the diagram is assumed to go through an entire detect-track-assign-engage sequence by interceptors, followed by loss of coverage by EW/GCI radars, by SAM encounter, by weapon launch/drop and by termination in that order. It must be remembered that individual penetrators do not necessarily experience this particular sequence, since the functions of Step 2 occur in the order dictated by the timing of the events in the simulation. Thus, for example, there may be SAM engagements before or concurrent with the interceptor command and control sequence, the weapon launches may be interspersed among the other events, loss of EW radar coverage may occur before the interceptor engagement is over, or there may be more than one interceptor assignment cycle experienced. If any of the engagements should result in a kill of the penetrator, subsequent events relating to that penetrator are bypassed.

2.5 SPEED I OUTPUTS

2.5.1 Detailed Simulation History

Figure 8 is a sample page of printout that summarizes the history of processed events and consequences. The user can request such printout for any subset of the Step 2 simulation cycles.

AI ENGAGEMENT	38	7718	19	[illegible]	3	2	1	4	0
TARGET DESIGNATION	45	7721	17	6	2	2	1	0	0
EW REPORT TO SC	5	7742	15	4	1	1	3	0	0
EW ZONE ENTRY	59	7745	[illegible]	2	1	2	537	0	0
EW ZONE ENTRY	49	7745	3	15	1	2	7	0	0
PENETRATOR TURNPT.	45	7754	9	0	0	2	0	0	0
EW ZONE EXIT	49	7755	4	15	1	2	0	0	0
TARGET DESIGNATION	49	7757	17	3	2	2	1	0	0
EW ZONE EXIT	18	7761	4	22	1	2	0	0	0
EW ZONE EXIT	19	7761	4	22	1	2	0	0	0
PENETRATOR TURNPT.	52	7762	9	0	0	2	0	0	0
EW ZONE ENTRY	62	7762	3	7	1	2	877	0	0
STR-TO-BT RPT TO SC	50	7765	16	119	1	2	31	0	0
EW REPORT TO SC	62	7770	15	7	1	2	2	0	0
PEN. TERMINAL POINT	102	7775	12	44	9	4	0	4	0
EW ZONE EXIT	49	7779	4	19	1	2	0	0	0
EW ZONE EXIT	49	7788	4	10	1	2	0	0	0
EW ZONE EXIT	49	7793	4	11	1	2	0	0	0
EW REPORT TO SC	59	7795	15	2	1	2	1	0	0
TARGET DESIGNATION	62	7801	17	2	2	2	1	0	0
TARGET DESIGNATION	59	7803	17	1	2	2	1	0	0
PENETRATOR TURNPT.	56	7804	9	0	0	2	0	0	0
EW ZONE EXIT	49	7820	4	13	1	2	0	0	0
EW REPORT TO SC	9	7823	15	119	1	1	31	0	0
ASSIGNMENT REASSESS	10	7829	18	119	1	1	0	0	0
TARGET DESIGNATION	9	7836	17	31	2	1	1	0	0
EW STROBE BURNTHRU	7	7839	14	119	1	1	1649	0	0
TARGET DESIGNATION	50	7841	17	31	2	2	1	0	0
TARGET DESIGNATION	5	7849	17	3	2	1	1	0	0
EW ZONE EXIT	49	7856	4	9	1	2	0	0	0
EW ZONE EXIT	49	7861	4	8	1	2	0	0	0
EW ZONE EXIT	49	7865	4	5	1	2	0	0	0
EW ZONE EXIT	49	7867	4	4	1	2	0	0	0
PENETRATOR TURNPT.	21	7868	9	0	0	2	0	0	0
STR-TO-BT RPT TO SC	49	7875	16	119	1	2	31	0	0
PENETRATOR TURNPT.	16	7892	9	0	0	2	0	0	0
EW ZONE EXIT	49	7893	4	6	1	2	0	0	0
TARGET DESIGNATION	49	7900	17	31	2	2	1	0	0
AI ENGAGEMENT	20	7904	19	18	3	2	2	1	0
EW ZONE ENTRY	59	7911	3	7	1	2	116	0	0
EW ZONE ENTRY	18	7917	3	23	1	2	269	0	0
EW ZONE EXIT	49	7916	4	1	1	2	0	0	0
EW REPORT TO SC	59	7920	15	7	1	2	2	0	0
ASSIGNMENT REASSESS	5	7925	18	1	4	1	0	0	0
EW STROBE BURNTHRU	49	7926	14	2	1	2	138	0	0
EW ZONE ENTRY	59	7927	3	3	1	2	97	0	0
PENETRATOR TURNPT.	22	7927	9	0	0	2	0	0	0
PENETRATOR TURNPT.	20	7930	9	0	0	2	0	0	0
STR-TO-BT RPT TO SC	49	7938	16	2	1	2	1	0	0
TARGET DESIGNATION	59	7942	17	2	2	2	1	0	0
TARGET DESIGNATION	49	7947	17	1	2	2	1	0	0
EW REPORT TO SC	18	7953	15	23	1	2	7	0	0
EW ZONE EXIT	5	7956	4	9	1	1	0	0	0
PENETRATOR TURNPT.	19	7956	9	0	0	2	0	0	0
AI ENGAGEMENT	17	7960	19	3	3	2	1	10	0
TARGET DESIGNATION	18	7966	17	7	2	2	2	0	0
PEN. TERMINAL POINT	103	7976	12	59	9	4	0	1	0
PENETRATOR TURNPT.	8	7978	9	0	0	1	0	0	0
EW REPORT TO SC	59	7988	15	3	1	2	1	0	0
PENETRATOR TURNPT.	62	7993	9	0	0	2	0	0	0
EW ZONE ENTRY	20	7999	3	24	1	2	340	0	0

ASSIGNMENT REASSESS.	38	8014	16	119	1	1	0	0	0	NO ENCOUNTER
TARGET DESIGNATION	5	7849	17	3	2	1	1	0	0	
										STROBE
EW REPORT TO SC	59	7795	15	2	1	2	1	0	0	
										STROBE
AI ENGAGEMENT	49	8045	19	22	3	2	1	7	0	
										STROBE
EW REPORT TO SC	62	7770	15	7	1	2	2	0	0	
TARGET DESIGNATION	50	7841	17	31	2	2	1	0	0	
TARGET DESIGNATION	62	7801	17	2	2	2	1	0	0	
										AIR BASE KILLED
TARGET DESIGNATION	59	7803	17	1	2	2	1	0	0	
TARGET DESIGNATION	9	7836	17	31	2	1	1	0	0	
ASSIGNMENT REASSESS.	10	8129	16	119	1	1	0	0	0	
STR-TO-BT REPT TO SC	7	8008	16	119	1	1	31	0	0	
AI ENGAGEMENT	5	8105	19	1	3	1	1	15	0	
TARGET DESIGNATION	49	7900	17	31	2	2	1	0	0	
ASSIGNMENT REASSESS.	20	8204	18	2	6	2	0	0	0	NO ENCOUNTER
										STROBE
EW REPORT TO SC	59	7920	15	7	1	2	2	0	0	
AI ENGAGEMENT	18	8429	19	25	3	2	2	5	0	BURNTHROUGH
EW REPORT TO SC	18	7953	15	23	1	2	7	0	0	
TARGET DESIGNATION	59	7942	17	2	2	2	1	0	0	
STR-TO-BT REPT TO SC	49	7938	16	2	1	2	1	0	0	
										STROBE
EW REPORT TO SC	59	7988	15	3	1	2	1	0	0	
TARGET DESIGNATION	49	7947	17	1	2	2	1	0	0	
ASSIGNMENT REASSESS.	45	8247	18	1	6	2	0	0	0	
TARGET DESIGNATION	18	7966	17	7	2	2	2	0	0	
										PENETRATOR KILLED
										AIR BASE KILLED
TARGET DESIGNATION	59	8018	17	1	2	2	1	0	0	
										BURNTHROUGH

Figure 8 STEP 2 SIMULATION HISTORY

The left-most literal entry plus the nine adjacent columns describe the event processed, the numerical entries representing, respectively: penetrator index, time (seconds), event type, defense entity index, defense entity type, penetrator type, and three additional quantities of variable definition. Thus, for example, EW ZONE ENTRY EVENT, designated by an asterisk on the far left, involves penetrator number 18 entering radar site number 23 at time 7917. The "1" signifies that the defense entity is in fact an EW/GCI/AWACS site and the "2" that the penetrator is one of that designated class. The "269" is the calculated exposure time, i.e., the penetrator will exit the visibility zone 269 seconds later.

The literal entry positioned roughly at the center of the page plus the nine adjacent columns to the right describe the additional derived event(s) generated by the event in process at the time (and which will subsequently be processed at the proper sequence in the simulation). Referring again to the asterisked line, we observe that both an AI ENGAGEMENT COMPLETED and an EW REPORT TO SUBCONTROL are generated. The latter is, of course, what one would expect. Note that this event is predicted to occur at time 7953, or 36 seconds later. The "7" identifies the subcontrol to which the report is made. Also, the "BURNTHROUGH" entry at the far right signifies that the nature of the detection was that of an immediate burnthrough of a jamming strobe.

The explanation for the new AI ENGAGEMENT COMPLETED event is that penetrator No. 18 is currently under AI engagement (AI number 25), had previously made an unobserved turn (so that the AI was still being vectored to an intercept based on the old penetrator track), and the current EW entry permitted the track to be updated and AI to be revectored. Engagement is predicted to occur at a revised location and time and, thus, needs to be recorded as a new event. The "2" and "5" in columns 7 and 8 refer, respectively, to the identity of the controlling ZOC and to a matching number that allows the model to reject the prior AI ENGAGEMENT COMPLETED event which has now been replaced.

Figure 9 is a composite of portions of several pages of printout which periodically summarizes the offensive and defensive state vectors during Step 2 simulation, again, printed at the option of the user. The PENETRATORS block covers such items as general status (LSTAT, LTAG), identity of engaging AI and controlling GCI (IAS, IKS), target status at ZOCs (JTRDIZ), time of last contact on tracked penetrators (LOSCON) and numbers of penetrators/weapons of different classes that remain to be launched (LUNL). The ZONAL OPERATIONS CENTERS and AWACS blocks provide data on numbers of target tracks (or detections) of different categories. The INTERCEPTORS block deals with AI currently in flight and includes: last recorded position/time (XXL, YYL, ZZL, ITIML), projected intercept point, if any, (XXI, YYI, ZZI, ITIMI), remaining fuel (RIFUEL), interceptor type (IID), and whether on CAP, loitering or engaging (ISTAT). The AIRBASES and SAM SITES blocks note operational status and remaining ground AI or missile inventory, the former by AI type.

2.5.2 Accumulated and Statistical Outputs

These outputs, in the form of tabulations and graphs, are illustrated in Figures 10 through 17. Since the main purpose here is to familiarize the reader with the forms as currently provided, and not to attempt any in-depth analysis of results, the outputs displayed have been taken from several unrelated runs.

In Figure 10 the first two lines display the aggregated time (in seconds) spent by two kinds of penetrators (B-52, SCAD) in various conditions relative to the AI defense process, shown in Figure 10A during a single cycle (replication). "NO INTERACTION" denotes the condition of: not currently detected, not an extrapolated target track, and not under engagement by a vectored AI. "C&C SYSTEM DELAYS" denotes the condition of having been detected but not having reached the point in information processing and transfer where a ZOC (or AWACS) is ready to attempt an AI assignment. The next three columns refer to saturation conditions under which an assigning center is prevented from following through against the penetrator in question because of some resource limitation. "AI ENGAGING" clearly means that the pene-

trator is under enegagement by a vectored AI. The six conditions covered add up to the "TOTAL TIME." "BLIND TIME" is an additional classification overlapping with the previous conditions. Time measurements on a penetrator are accumulated only following initial detection by some radar. The next two lines in the figure transform the results to percentage of TOTAL TIME. The bottom portion of the figure presents the mean estimate and the mean ± two standard deviations of this estimate for each percentage measure taken over all replications.

Figure 11 displays all of the "unnatural" terminations for each of two classes of penetrators within a single replication. For each such termination the time, cause, coordinates, and accumulated range flown are given. When the cause is AI or SAM kill, the AI or SAM type is noted. "LAUN" signifies a failure at launch. "UNLA" signifies that penetrator was unlaunched because parent aircraft had previously been killed.

Figures 12 and 13 are reasonably self-explanatory. Since the distribution and time histories are averaged *over all replications*, the mean estimates are accompanied by ± two standard deviation bounds about these estimates.

Figure 14 summarizes the attrition measures for penetrator types over all replications. Again, kills by AI and SAM entities are subdivided by type. The entries are estimated mean numbers of penetrators of each class terminated by the specific mechanisms, along with ± two standard deviation bounds about these estimates. The mechanism "CLOBBER" refers to inflight failure; the term comes from one possible source for inflight failure; namely, a malfunction of the automatic terrain avoidance system resulting in ground impact.

Figure 15 provides a further analysis of the AI and SAM engagement process by estimating mean numbers of AI assignments, AI encounters, AI kills, SAM engagements, and SAM kills. (See paragraph 2.3.4 for clarification of these terms.) The P(·/·) entries refer to estimates of various conditional

probabilities for the particular conditions of the simulated scenario, the mix of AI and SAM types, and the penetration altitudes actually realized.

Figures 16 and 17 illustrate some of the automatic LDX plots that are provided as adjuncts to the tabular outputs.

STATE VECTORS AT TIME 8000

PENETRATORS

PEN. NO.	LSTAT	LTAG	IAS	IKS	JCGV	KNTGCI	NIR		JTADIZ					LESCAN(L,I),I=1,5					LOTI(L,I),I=1,5					CONE(LI,L)			
1	106	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	458	452	452	457	452	0	0	0	4
2	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7491	7491	7491	7491	7491	0	0	0	4
3	105	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1650	1650	1650	1650	1650	0	0	0	0
4	161	9	0	0	0	0	0	0	0	0	0	0	32767	0	0	0	0	0	32757	6750	6750	6750	6750	6	0	0	4
5	1	6	1	9	0	0	1	3	0	0	0	0	1950	0	0	0	0	0	32767	7705	7705	7705	7705	0	0	0	0
6	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4515	7252	7252	7252	7252	0	0	0	4
7	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5844	6967	6967	6967	6967	6	0	0	4
8	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6234	7478	7478	7478	7478	0	0	8	4
9	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6656	7589	7589	7589	7589	0	0	0	4
10	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7314	7314	7314	7314	7314	0	0	6	4
11	106	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1653	1653	1653	1653	1653				
12	9	9	0	0	0	0	0	0	0	0	0	0	32767	0	0	0	0	0	32767	5069	5069	5069	5069				
13	106	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	32767	1474	1474	1474	1474				

ZONAL OPERATIONS CENTERS

KZ	NZGOTS	NZGOTI	NZGOTP	NZDISS	NZDIST	NZDISP	NZGOT	NZIAS
1	0	0	2	0	0	0	2	2
2	0	0	3	0	0	0	3	3
3	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0

AWACS

AWACS NO.	NEDET(1,I)	NEDET(2,I)	NEDET(3,I)
119	16	0	5
120	0	0	0

INTERCEPTORS

INT.NO.	XXL	YYL	ZZL	XXI	YYI	ZZI	RIFUEL	IID	ISTAT	ITIML	ITIMI	KEY	IBORIG	IIGAP
1	-94190.	274940.	1500.	-163402.	368236.	1500.	16047.	1	1	7969	8105	15	2	0
2	-62731.	440272.	1500.	0.	0.	0.	40444.	5	3	0	0	0	1	0
4	-62731.	440272.	1500.	125745.	686197.	13700.	17195.	1	3	7703	7163	4	1	0
5	-35004.	-8539.	1500.	0.	0.	0.	9000.	7	3	0	0	0	3	0
6	-131974.	451548.	1500.	-131974.	451548.	1500.	25944.	4	2	7925	7625	2	4	0
7	-164820.	-926172.	1500.	0.	0.	0.	9000.	7	3	0	0	0	5	0

AIRBASES

BASE	IBSTAT	IBINVG(B,KA)							
1	0	1	0	0	0	7	0	0	0
2	1	9	0	0	0	0	0	0	0
3	1	0	0	0	0	0	0	9	0

SAM SITES

1- 50	NSTAT=	9 9 9 9 9	9 9 9 9 9	9 9 9 9 9	9 9 9 9 9	9 9 9 9	9 9 9 9 9	9 9 9 9 9	9 9 9 9 9	9 9 9 9 9	9 9 9 9 9
	NINV=	2424242424	2424242424	2424242424	2424242424	2424242424	2424242424	2424242436	3636363636	3636363636	3636363636
51-100	NSTAT=	9 9 9 9 9	9 9 9 9 9	9 9 9 9 9	9 9 9 9 9	9 9 9 9 9	9 9 9 9 9	9 9 9 9 9	9 9 9 9 9	9 9 9 9 9	9 9 9 9 9
	NINV=	3636363636	3636363636	3636363636	3636363636	3636363636	3636363636	3636362424	2424242424	2424242424	2424242424

Figure 9 STEP 2 PERIODIC STATE VECTOR SUMMARY

TEST STEPS, 5REPS, 4OUP/REP, BASE CASE, AREA1 NCASE 805 IDEN 12 1 8 0 REP 5 3MAR'73

AI DEFENSE ENGAGEMENT EFFICIENCY

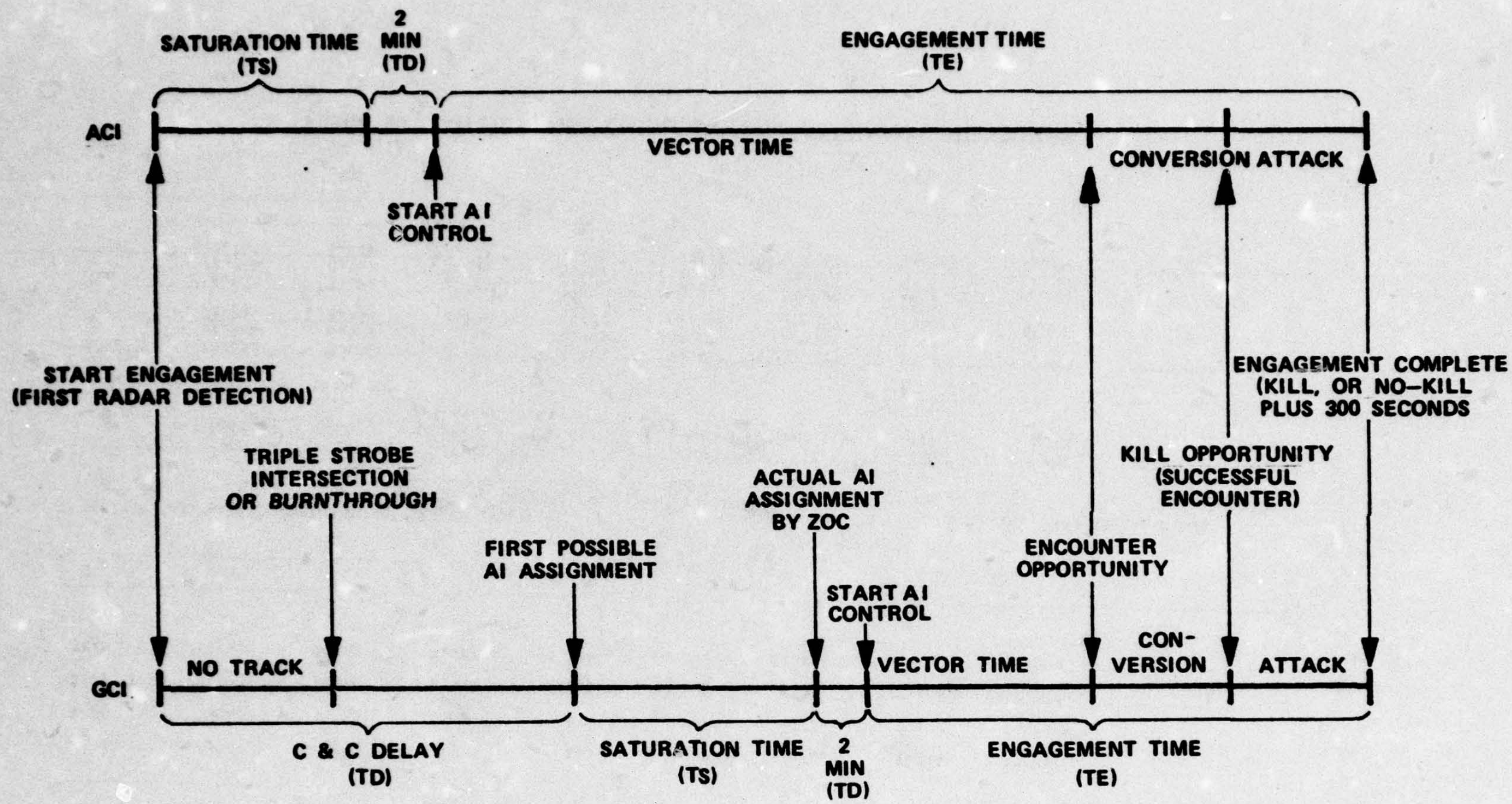
	NO INTERACTION	CCC SYSTEM DELAYS	SATURATED NO NETTED GCI AVAIL	SATURATED CLOSEST AVAIL GCI TOO FAR	SATURATED NO AI	AI ENGAGING	BLIND TIME	TOTAL TIME
B-52	17068	7580	1500	643	45784	12726	16314	85301
SCAD	24363	15555	9000	4587	147940	40715	30178	242160
B-52	20.009	8.886	1.758	0.754	53.673	14.919	19.125	100.000
SCAD	10.061	6.423	3.717	1.894	61.092	16.813	12.462	100.000

TEST STEPS, 5REPS, 4OUP/REP, BASE CASE, AREA1 12 IDEN 1 8 0 20 *** REPLICATIONS

AVERAGE AI DEFENSE ENGAGEMENT EFFICIENCY

	NO INTERACTION	CCC SYSTEM DELAYS	SATURATED NO NETTED GCI AVAIL	SATURATED CLOSEST AVAIL GCI TOO FAR	SATURATED NO AI	AI ENGAGING	BLIND TIME	TOTAL TIME
B-52	19.251	3.122	0.822	0.443	55.431	12.045	20.533	100.000
	21.496	5.028	1.488	0.707	57.875	13.406	23.805	100.000
	23.741	6.934	2.154	0.971	60.319	14.767	27.077	100.000
SCAD	9.583	5.070	3.256	1.062	58.219	17.756	19.725	100.000
	11.375	5.567	3.939	1.254	58.926	18.938	32.113	100.000
	13.168	6.064	4.622	1.446	59.634	20.120	44.502	100.000

Figure 10 AI DEFENSE ENGAGEMENT EFFICIENCY MEASURES



NOTES:

CONVERSION INCLUDES TERMINAL MANEUVER, DETECTION, LOCK–ON, AND TRACK (0 TIME)
ATTACK INCLUDES MISSILE FIRING(S), AND MULTIPLE PASSES (0 TIME)
BURNTHROUGH AFTER START OF AI CONTROL EFFECTS ACI PROBILITY-OF-ENCOUNTER, NOT TIME TO INTERCEPT

Figure 10A AI DEFENSE PROCESS IN SPEED MODEL

S2 AREA1,NO NAV./GUID ERROR N=10 NCASE 108 IDEN 4 2 0 0 REP 8 28OCT'72

DETAILED B52 ATTRITION DATA

ID	TIME OF KILL	THREAT	TYPE	DECOYS ABOARD	X	Y	Z
4	3362	AI	4	6	-632146.	407379.	13700.
3	6526	AI	4	0	-138272.	-178821.	76.
5	8948	AI	4	0	-76220.	-154175.	76.
8	10657	SAM	5	0	1009.	118564.	76.

DETAILED DECOY ATTRITION DATA

ID	TIME OF KILL	THREAT	TYPE	DECOY TYPE	X	Y	Z	R
15	660	LAUN	0	SCUD	0.	0.	0.	0.
14	660	LAUN	0	SCUD	0.	0.	0.	0.
16	1981	AI	4	SCUD	-703102.	241677.	13700.	181.
19	2538	LAUN	0	SCUD	0.	0.	0.	0.
12	3641	AI	4	SCUD	-373256.	305559.	12674.	383.
26	4178	AI	4	SCUD	-469844.	444723.	13700.	304.
31	4218	UNLA	0	SCUD	0.	0.	0.	0.
29	4218	UNLA	0	SCUD	0.	0.	0.	0.
30	4218	UNLA	0	SCUD	0.	0.	0.	0.
33	4218	UNLA	0	SCUD	0.	0.	0.	0.
32	4218	UNLA	0	SCUD	0.	0.	0.	0.
34	4218	UNLA	0	SCUD	0.	0.	0.	0.
40	4260	LAUN	0	SCUD	0.	0.	0.	0.
38	4260	LAUN	0	SCUD	0.	0.	0.	0.
52	5460	LAUN	0	SCUD	0.	0.	0.	0.
48	5460	LAUN	0	SCUD	0.	0.	0.	0.
23	5620	AI	4	SCUD	-352000.	345009.	13030.	482.
20	5650	SAM	5	SCUD	-36536.	13925.	229.	372.
13	6039	AI	1	SCUD	-9805.	89493.	229.	618.
11	6560	SAM	5	SCUD	-39891.	21647.	229.	703.
21	6635	SAM	5	SCUD	-55176.	-140396.	229.	471.
18	6835	SAM	5	SCUD	-19405.	58227.	229.	492.
22	6993	SAM	5	SCUD	-35674.	19402.	229.	515.
44	7625	AI	4	SCUD	-366388.	53402.	13645.	206.
28	7755	SAM	5	SCUD	-35249.	18882.	229.	660.
45	7838	AI	4	SCUD	-470861.	-89802.	3420.	232.
41	7903	AI	4	SCUD	-236926.	336840.	13700.	241.
27	8127	SAM	5	SCUD	-129885.	-213281.	229.	702.
25	9217	SAM	5	SCUD	137117.	28177.	229.	812.
43	9427	SAM	5	SCUD	-61806.	-87628.	229.	399.
39	9901	SAM	5	SCUD	38296.	183616.	229.	638.
56	10429	SAM	5	SCUD	-116206.	-40609.	229.	369.
53	10837	SAM	5	SCUD	64136.	169063.	229.	411.
35	10865	SAM	5	SCUD	36008.	191067.	229.	723.
55	11228	SAM	5	SCUD	-34128.	20829.	229.	449.
54	11803	SAM	5	SCUD	150919.	28478.	229.	507.
49	12117	SAM	5	SCUD	143015.	138715.	229.	733.
64	12306	SAM	5	SCUD	-4934.	44163.	229.	33.
62	12666	SAM	5	SCUD	69730.	-23305.	229.	85.
63	12769	SAM	5	SCUD	72451.	-56230.	229.	101.
70	14308	SAM	5	SCUD	290621.	-132331.	229.	43.
67	16385	SAM	4	SCUD	454785.	302117.	229.	385.

Figure 11 PENETRATOR ATTRITION EVENTS

S2 AREA1,NO NAV./GUID ERROR   N=10   IDEN 4 2 0 0   10 REPLICATIONS   28OCT'72

AVERAGE DISTRIBUTION OF DECOY RANGES AT KILL OR TERMINATION
IN 50 N.MI INCREMENTS

RANGE	NO. OF DECOYS	CUM NO. OF DECOYS
0- 49	8.863	8.863
	11.500	11.500
	14.137	14.137
50- 99	0.273	9.580
	0.600	12.100
	0.927	14.620
100- 149	0.873	11.049
	1.300	13.400
	1.727	15.751
150- 199	0.578	11.832
	1.000	14.400
	1.422	16.968
200- 249	0.967	13.598
	1.700	16.100
	2.433	18.602
250- 299	0.404	14.426
	1.000	17.100
	1.596	19.774
300- 349	0.471	15.375
	1.100	18.200
	1.729	21.025
350- 399	4.271	20.651
	4.900	23.100
	5.529	25.549
400- 449	1.633	22.856
	2.100	25.200
	2.567	27.544
1950-1999	0.0	60.000
	0.0	60.000
	0.0	60.000
2000-****	0.0	60.000
	0.0	60.000
	0.0	60.000

AVERAGE RANGE FLOWN BY DECOYS IS   479.158 N. MI.
STANDARD DEVIATION IS   301.735

Figure 12 RANGE DISTRIBUTION FOR ONE PENETRATOR CLASS

TEST STEP3, SREPS, 600?/REP, BASE CASE, AREA1   12 IDFN 1 H 0 20 *** REPLICATIONS

AVERAGE TIME HISTORY MEASURES

TIME INTERVAL (SECS)	NO. OF [illegible] SURVIVING	NO. OF WEAPONS DELIVERED SCADS	HOU.	SRAM	G.P.	TOTAL	NO. OF AI ENCOUNTERS OF B52'S	NO. OF DECOYS IN FLIGHT
0- 299	10.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	10.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	10.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
300- 599	10.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	10.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	10.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
600- 899	10.0	0.0	0.0	0.0	0.0	0.0	0.0	5.4
	10.0	0.0	0.0	0.0	0.0	0.0	0.0	5.8
	10.0	0.0	0.0	0.0	0.0	0.0	0.0	6.2
900- 1199	10.0	0.0	0.0	0.0	0.0	0.0	0.0	5.4
	10.0	0.0	0.0	0.0	0.0	0.0	0.0	5.8
	10.0	0.0	0.0	0.0	0.0	0.0	0.0	6.2
1200- 1499	10.0	0.0	2.0	0.0	0.0	2.0	0.0	5.4
	10.0	0.0	2.0	0.0	0.0	2.0	0.0	5.8
	10.0	0.0	2.0	0.0	0.0	2.0	0.0	6.2
1500- 1799	10.0	0.0	2.0	0.0	0.0	2.0	0.0	5.4
	10.0	0.0	2.0	0.0	0.0	2.0	0.0	5.8
	10.0	0.0	2.0	0.0	0.0	2.0	0.0	6.2
1800- 2099	10.0	0.0	2.0	0.0	0.0	2.0	0.0	9.5
	10.0	0.0	2.0	0.0	0.0	2.0	0.0	10.3
	10.0	0.0	2.0	0.0	0.0	2.0	0.0	11.1
2100- 2399	9.6	0.0	2.0	0.0	0.0	2.0	0.3	8.0
	9.8	0.0	2.0	0.0	0.0	2.0	0.4	8.7
	10.0	0.0	2.0	0.0	0.0	2.0	0.6	9.4
2400- 2699	9.6	0.0	4.0	0.0	0.0	4.0	0.3	11.0
	9.8	0.0	4.0	0.0	0.0	4.0	0.4	12.7
	10.0	0.0	4.0	0.0	0.0	4.0	0.6	14.4
24900-25199	6.2	0.0	6.0	45.1	25.2	76.5	4.1	0.0
	7.0	0.0	6.0	50.8	28.3	85.1	4.8	0.0
	7.9	0.0	6.0	56.5	31.5	93.8	5.4	0.0
25200-*****	6.2	0.0	6.0	45.1	25.2	76.5	4.1	0.0
	7.0	0.0	6.0	50.8	28.3	85.1	4.8	0.0
	7.9	0.0	6.0	56.5	31.5	93.8	5.4	0.0

Figure 13 TIME HISTORY OF SELECTED MEASURES

S2 AREA1,NO NAV./GUID ERROR N=10 IDEN 4 2 0 0 10 REPLICATIONS 28OCT'72

AVERAGED ATTRITION SUMMARY

AI TYPE

	1	2	3	4	5	6	7	8	TOTAL	PERCENT
B-52	-0.09	0.0	0.0	0.40	0.0	0.0	0.0	0.0	0.75	0.08
	0.70	0.0	0.0	1.00	0.0	0.0	0.0	0.0	1.70	0.17
	1.49	0.0	0.0	1.60	0.0	0.0	0.0	0.0	2.65	0.26
SCUD	1.09	0.0	0.0	3.56	0.0	0.0	-0.04	0.0	5.69	0.09
	2.20	0.0	0.0	4.60	0.0	0.0	0.50	0.0	7.30	0.12
	3.31	0.0	0.0	5.64	0.0	0.0	1.04	0.0	8.91	0.15
SCAD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

SAM TYPE

	1	2	3	4	5	6	7	8	TOTAL	PERCENT
B-52	0.0	0.0	0.0	0.0	-0.10	0.0	0.0	0.0	-0.10	-0.01
	0.0	0.0	0.0	0.0	0.10	0.0	0.0	0.0	0.10	0.01
	0.0	0.0	0.0	0.0	0.30	0.0	0.0	0.0	0.30	0.03
SCUD	0.0	0.0	0.0	1.33	22.49	0.0	0.0	0.0	24.34	0.41
	0.0	0.0	0.0	2.00	25.20	0.0	0.0	0.0	27.20	0.45
	0.0	0.0	0.0	2.67	27.91	0.0	0.0	0.0	30.06	0.50
SCAD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

	CLOBBER	CLOBBER PRCNT	FAILED AT LAUNCH	FAILED PRCNT	UNLAUNCHED	UNLAUN. PRCNT
B-52	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	C.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0
SCUD	0.0	0.0	5.01	0.08	0.95	0.02
	0.0	0.0	6.10	0.10	3.60	0.06
	0.0	0.0	7.19	0.12	6.25	0.10
SCAD	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0

Figure 14 PENETRATOR ATTRITION SUMMARY

5 REPS (4,8,12,16,20), 4 DUPS/REP, AREAL, BASE CASE　　IDEN 12 1 P 0 20 REPLICATIONS 27578173

AI VS. B-52

ASSIGNMENTS	ENCOUNTERS	KILLS	P(K/A)	P(E/A)	P(K/E)
17.31	2.75	1.85	0.10	0.15	0.62
18.35	3.65	2.65	0.15	0.20	0.74
19.39	4.55	3.45	0.19	0.24	0.85

AI VS. SCAD

ASSIGNMENTS	ENCOUNTERS	KILLS	P(K/A)	P(E/A)	P(K/E)
73.55	18.87	11.80	0.15	0.24	0.59
79.15	20.70	13.20	0.17	0.26	0.64
84.75	22.59	14.60	0.18	0.28	0.70

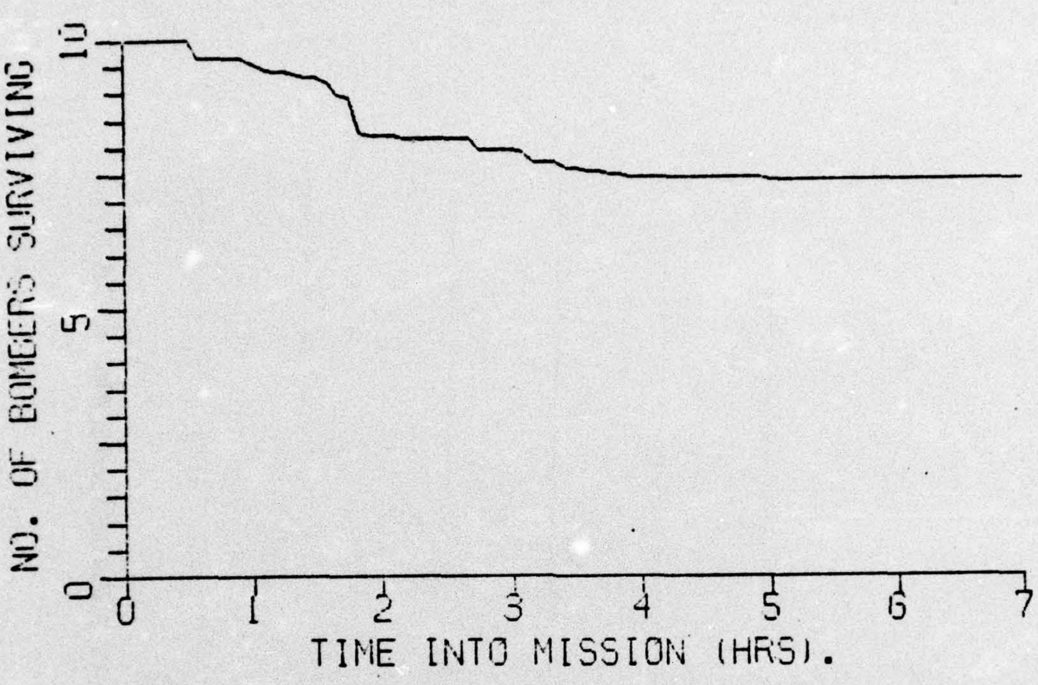
SAM VS. B-52

ENGAGEMENTS	KILLS	P(K/E)
3.67	0.00	0.00
4.10	0.25	0.06
4.53	0.50	0.12

SAM VS. SCAC

ENGAGEMENTS	KILLS	P(K/E)
49.66	20.35	0.40
52.75	21.90	0.42
55.84	23.45	0.43

Figure 15 STATISTICS OF ASSIGNMENTS, ENCOUNTERS, ENGAGEMENTS, AND KILLS



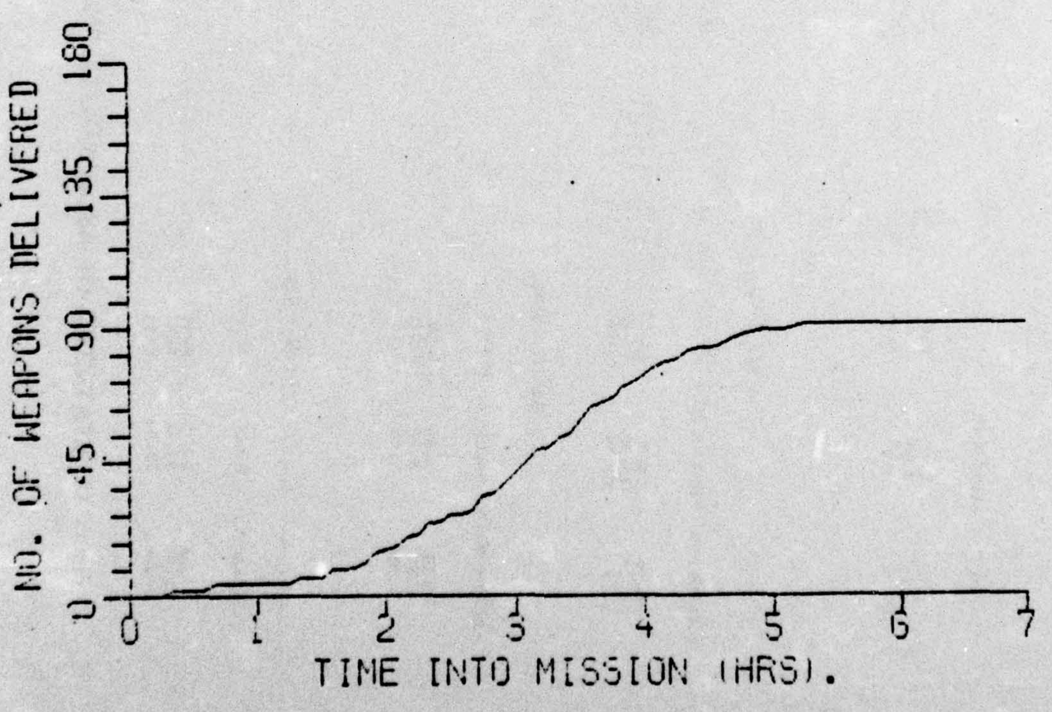
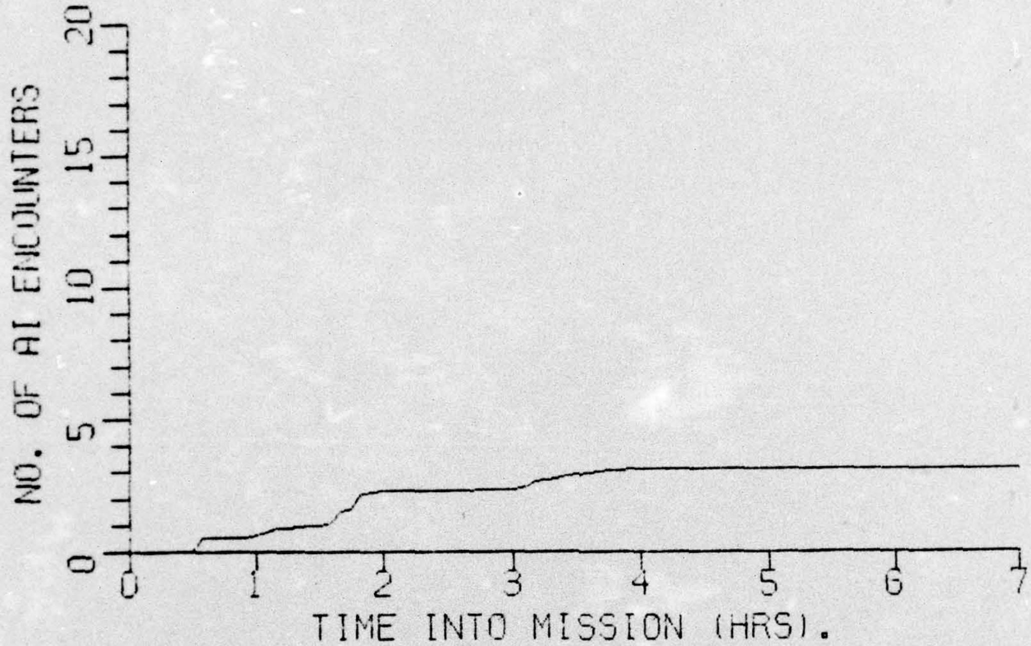


Figure 16 (U) SAMPLE OUTPUT PLOTS I



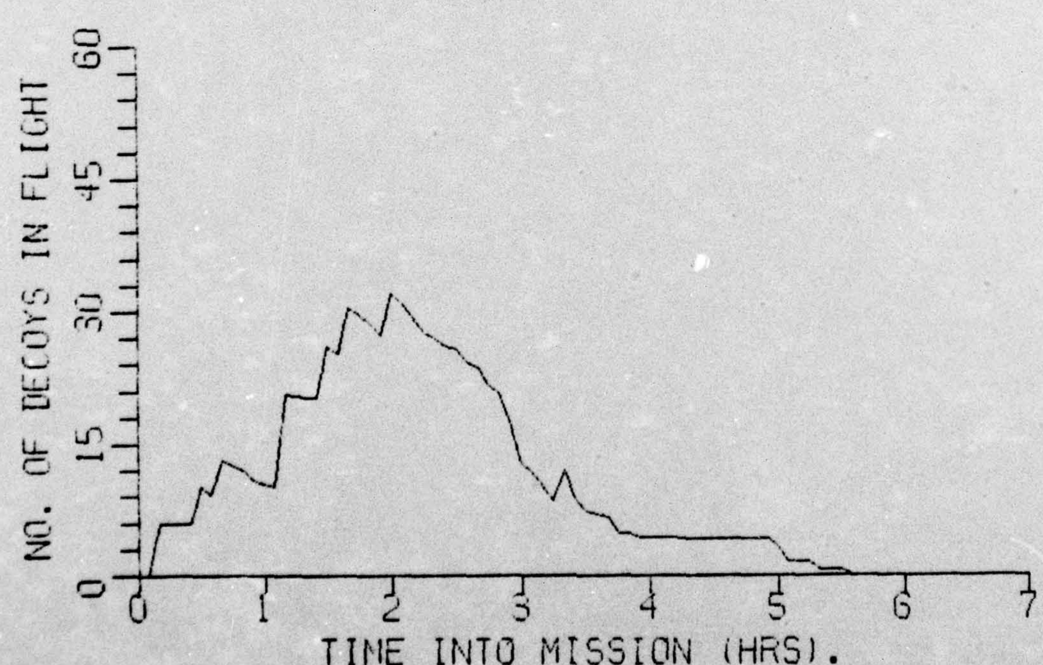


Figure 17 SAMPLE OUTPUT PLOTS II

SECTION III

SPEED APPLICATIONS

The SPEED Model has the capability to provide traceability of variations in penetration effectiveness relative to variations in SCAD design. The model outputs vary at the user's option from such overall mission measures as bomber survivability and weapons delivered to extremely detailed outputs such as a record of each event as it occurred during the simulation. This allows the user to determine not only how effectiveness varies, but also why effectiveness varies as the inputs are modified. Thus, the model is a useful management tool as well as an engineering analytical tool by providing data for trade study decisions, by tracking system effectiveness during development and testing, by defining sensitivities to threat variations, and by providing data for risk analysis. Figure 18 relates the SPEED Model to the various other models and simulators available within the AGM-86A Program Office to support SCAD development.

3.1 MODEL VALIDATION

In order to verify that the model indeed provided the required insight into the relationship between SCAD design and penetration effectiveness, an initial series of tests were performed with the model. The test conditions and test results are fully described in Calspan Report No. TA-5175-Q-11. Briefly, the test included variations in SCAD design, variations in the threat, variations in penetration tactics, and variations in the effectiveness of other penetration aids such as SRAM, HOUND DOG II and ECM. Analysis of the test results indicated that all of the results and the relative magnitude of the variations were consistent with prior estimates and/or after-the-fact analyses. (Several test results were somewhat surprising until subsequent analysis established that the results were indeed consistent with the test conditions.) In addition to providing the relative magnitude of various effects, the test results also indicated a number of possible trade-offs between SCAD design and employment tactics which had not previously been iden-

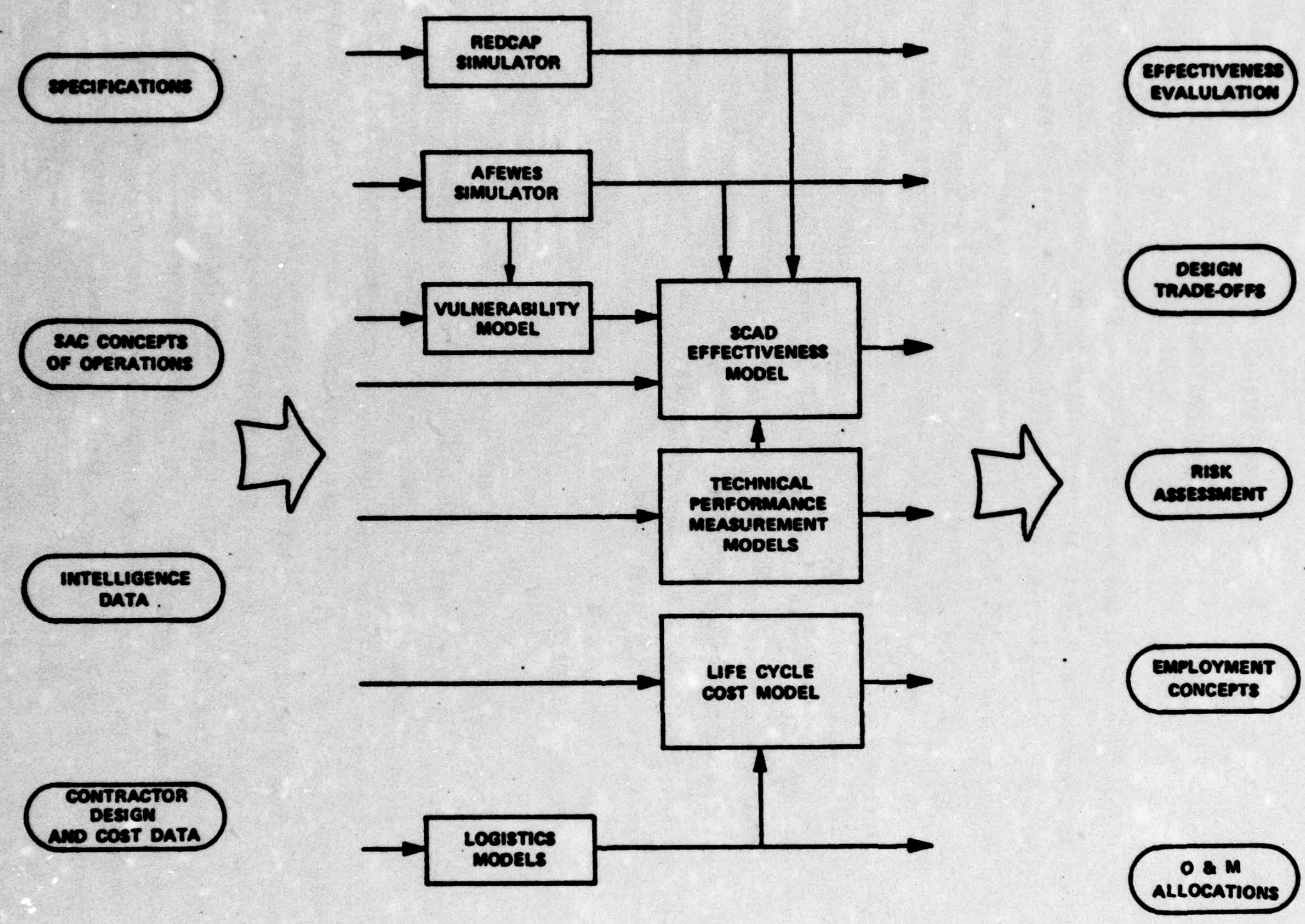


Figure 18 MODELING AND SIMULATION IN SUPPORT OF AGM-86A DEVELOPMENT

tified. To date, approximately 110 sensitivity tests (approximately 1300 test runs) have been performed with the model.

3.2 PLANNED UTILIZATION

In order to minimize the cost of a program and to assure against large cost overruns and/or large reductions from required to actual performance, a number of engineering management procedures have been instituted within the AGM-86A Program Office. These procedures are designed to detect SCAD development problems, and to generate and evaluate alternative solutions. In many cases, one of the primary evaluation criteria is the impact of a potential decision on the effectiveness of the system under development. The SPEED model is an excellent source of data for these evaluations.

Over one hundred runs (of 20 to 32 replications each) have been made with the model to provide data for the evaluation of various alternatives by the SCAD Program Office. These include the following test series: a) tests in support of the EW Mission Analyses Group, b) SCAD range study, c) SCAD ECM (Module V) trade study, and d) tests to determine the potential impact of EMP exposure. These studies are discussed in Calspan Report No. TA-5175-Q-24.

3.2.1 Technical Performance Measurement

One of the methods employed to track the development of a weapons system and to identify developing problem areas is Technical Performance Measurement (TPM). Under this procedure, the performance of each subsystem is periodically assessed during the development process and predictions made concerning the expected performance of the production version. Figure 19 provides an example of the periodic output of this process. In order to meaningfully assess the extent of the impact of variations from specifications as they are reported, a method of combining all the values of the parameters into a single or small set of numbers related to the effectiveness of the system is required. For the SCAD program, SPEED can accomplish this objective. By periodically rerunning a specifically selected series of base cases, SPEED

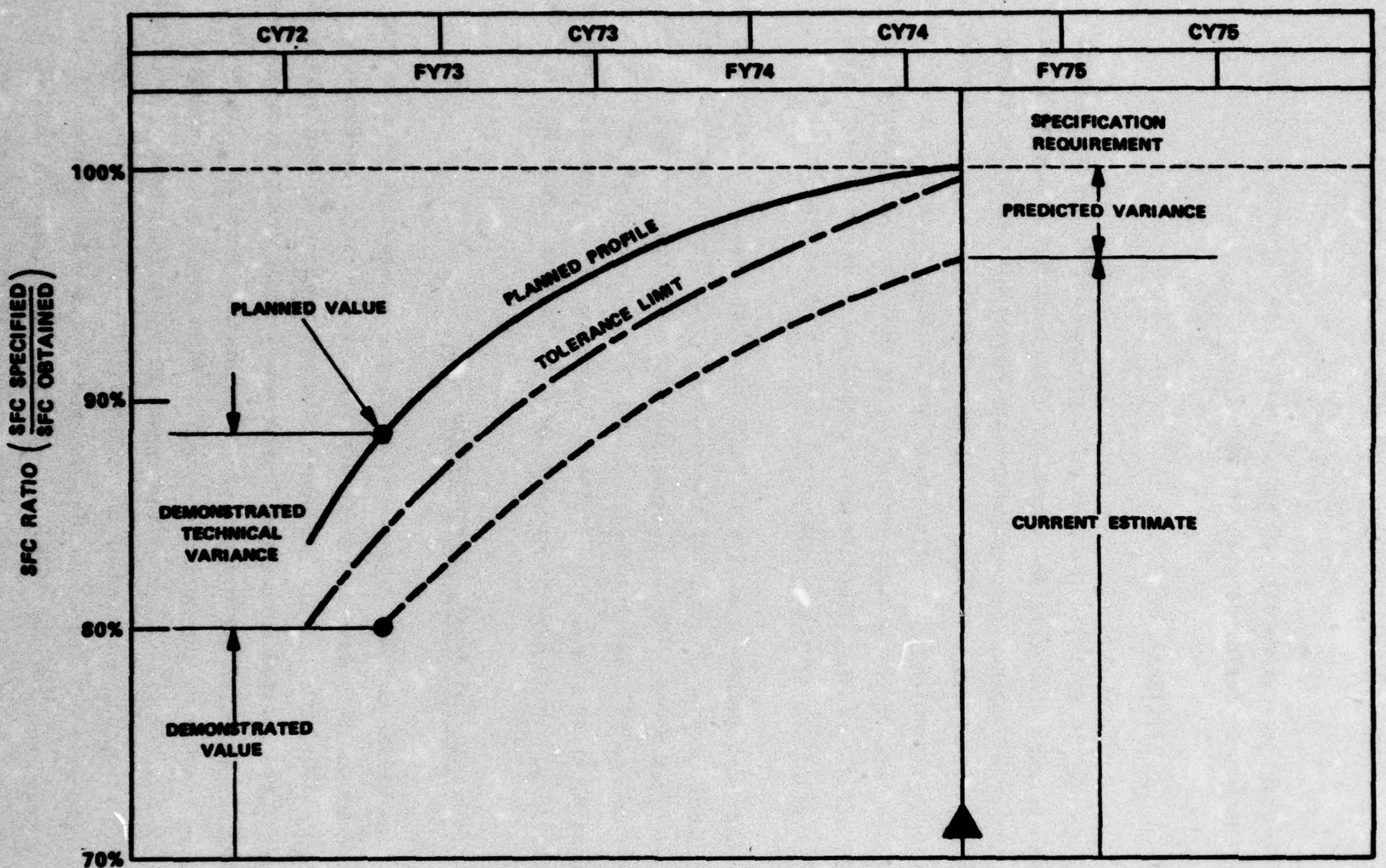


Figure 19 PROFILE PREDICTION BASED ON DEMONSTRATED VALUE

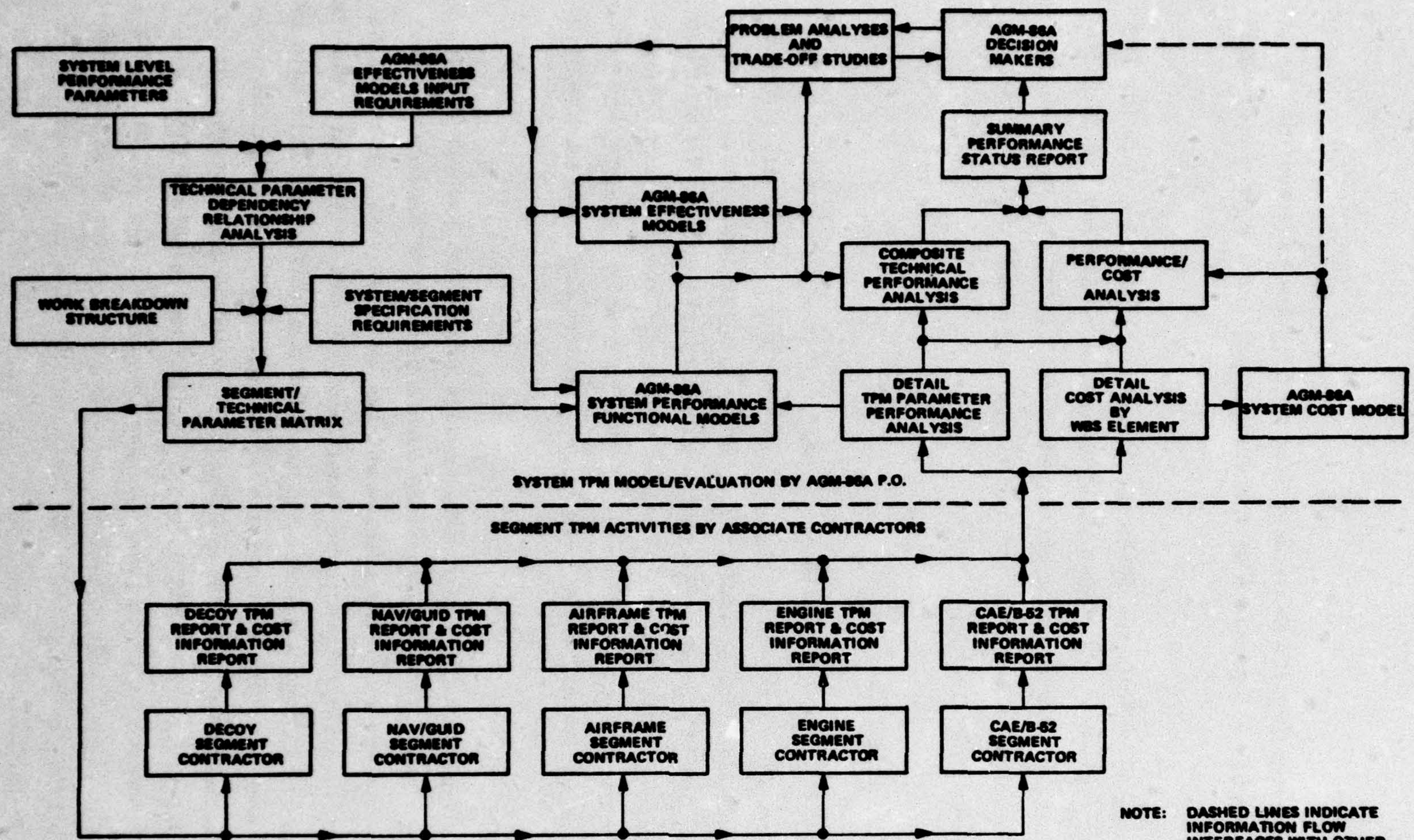
outputs can provide Program Management with an overview of trends in the program and the relative importance of the various performance parameter variations.

Figure 20 relates the SPEED Model to the information flow for TPM. As the figure indicates, the SPEED Model is used not only for the periodic reporting of the status (current estimated effectiveness) of the SCAD, but also as problems and trade-offs are identified to provide data for making the required decisions.

3.2.2 Risk Management

A fundamental problem with any weapon system development program is the assessment and reduction of the risk that the program will not meet one or more of the cost, schedule, or performance goals that are initially set. In addition, there are more subtle program risks such as funding cuts, threat changes, and program stretchouts that must be considered. The TPM program discussed above provides some of the information required for risk assessment and analysis; however, additional studies and analyses are also required.

The fundamental process within a risk management program is the generation and analysis of alternatives when a particular problem arises. Depending on the nature of the problem and the alternatives, variations in system effectiveness may have to be considered. Figure 21 indicates how various models and simulators may be used to solve a specific (in this case hypothetical) problem. The particular problem could have arisen in any number of ways. For instance: 1) the specification value is unachieveable without a schedule delay, 2) the specification value is unachievable without cost overruns, 3) the reduction in power has been suggested as a weight saving feature, etc. In each case, however, the questions represent an alternative which has to be assessed in terms of its impact on SCAD effectiveness, as well as other factors.



NOTE: DASHED LINES INDICATE INFORMATION FLOW INTERFACES WITH OTHER TECHNICAL/MANAGEMENT INFORMATION ACTIVITIES

Figure 20 TECHNICAL PERFORMANCE MEASUREMENT (TPM) INFORMATION FLOW CHART

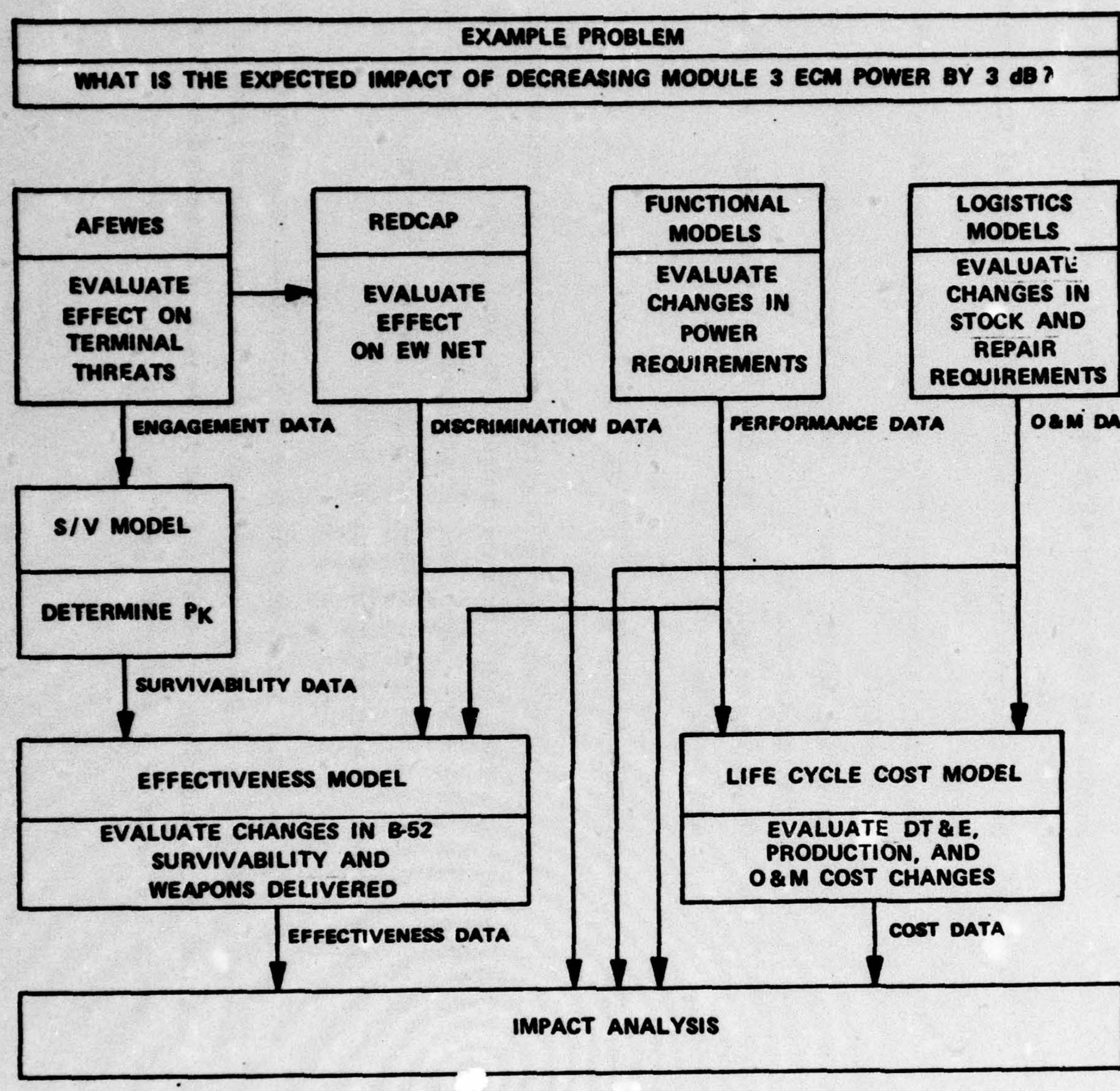


Figure 21 EXAMPLE OF USE OF MODELS AND SIMULATIONS IN SOLVING A SPECIFIC PROBLEM

3.2.3 Other Applications

In addition to the above applications to management processes, other applications of SPEED to the SCAD Program include:

a. Evaluating the impact on SCAD design of new estimates of threat capabilities,

b. Evaluating the impact on SCAD design of potential SCAD employment tactics,

c. Examining the compatibility of SCAD with other weapons systems such as B-1,

d. Providing insight into the sensitivity of SCAD effectiveness to employment tactics,

e. Providing insight into the trade-offs between SCAD and competing and complementing systems.

3.3 APPLICABILITY TO OTHER PROGRAMS

Although SPEED was designed with the objective of evaluating SCAD performance in a total mission environment, its applicability is not limited to SCAD. For instance, appropriate input changes could replace the B-52s by F-4s, SCAD by RPVs, SRAM by tactical AGMs, and the initially inputted EOB/AOB by one at another geographical area.

In addition, the model has been so structured as to minimize the effort involved in modifying the various concepts and elements modeled. This allows rapid additions or modifications to be made when needed to consider special effects of a particular penetration problem.

SECTION IV

MODEL GROWTH AREAS

As with any well constructed model, provisions have been made in the SPEED model structure for growth and modification. To some extent, provisions have already been included in the coding for expected growth features. These provisions were included although lack of precise data precluded complete modeling of specific effects or features in the first version of the model. The model tests conducted to date have also served to point out some areas where model improvement should be considered and other areas where model refinements are not required. This section discusses some of the model growth areas which are currently being considered, and some of the modifications which have been proposed and analyzed but do not warrant implementation at this time.

4.1 PENETRATOR CHARACTERISTICS

The SPEED model currently considers three basic types of penetrators: bombers, decoys, and weapons. Although the modeled characteristics overlap (i.e., armed decoys can be employed as weapons, and certain weapons can be intercepted and killed similar to bombers or decoys) this categorization into three types is quite useful from the standpoint of modeling logic.

4.1.1 Bomber Characteristics

The following areas of model growth in the area of bomber characteristics have been or are being considered: navigation errors, reactive ECM, reactive flight profiles, turn times and radii, and fuel consumption rates.

Since the intended use of the model is primarily to simulate that portion of the bomber's flight where SCAD makes a contribution to bomber survivability, bomber fuel consumption rates are immaterial except from the

standpoint of defining the input flight profiles. Thus, calculations of bomber fuel usage would not contribute significantly to currently contemplated analyses. Analysis of the impact of realistic turn times and distances (as opposed to instantaneous turns) indicates the relatively small values of these parameters will have no significant effect on model results. Thus, revision of the currently employed approximation (instantaneous turns) is not planned. Reactive bomber profiles (i.e., revision of the input profiles based on probable crew decisions given the current status of the penetration) would require a major rewrite of the model and would increase the running time considerably. Further, the impact of such reactions on SCAD effectiveness is considered to be minimal. However, reactive bomber ECM is a planned addition because of its large impact on bomber survivability and its relationship to decoy discrimination. Bomber navigation errors are of interest for two reasons: 1) the possibility of bomber fratricide if large numbers of armed SCADs are employed and 2) the impact of mistimed and misplaced SCAD launches. This feature is thus planned to be incorporated.

4.1.2 Decoy Characteristics

Because of the initial purpose of the model, the decoy is, of course, extensively modeled. However, two features not included in the initial model because of the lack of definitive data will be added: 1) decoy discrimination and 2) alternate decoy launches.

4.1.3 Weapon Characteristics

Currently, most of the weapons modeled automatically kill their targets if they are launched and if they are not killed on the way to the target (DGZ). This feature will be modified to include launch and inflight weapon reliabilities, weapon terminal position errors, and probability of kill as a function of target type, miss distance, and weapon yield.

4.2 THREAT AIRBORNE INTERCEPTORS (AIs)

There are a number of candidate model modifications in the area of threat AIs. These include:

a) Addition of AI recycling,
b) Modification of AI assignment/reassignment rules,
c) Addition of AI/GCI communications,
d) Modifications of AI detection modeling, and
e) Modifications of AI weapon expenditure modeling.

Two areas of AI recycling will be considered: 1) fuel reloading only, and 2) fuel and armament reloading. Reliability/maintainability factors associated with recycling are not planned to be included. In conjunction with the addition of decoy discrimination, the AI assignment and reassignment rules will be modified to reflect reactions to discrimination. In addition, reassignment logic will be modified to include a prioritized target list and return-to-base. AI/GCI communication will be added (1) to model the effect of AI/GCI interchange of information relative to decoy discrimination by AIs, and (2) to allow the possibility of AIs providing raid count data to the command net sites in an ECM environment. AI detection/search capability will be more extensively modeled to permit evaluation of the impact of AI discrimination and raid count data. Modeling of AI weapon expenditure will be modified to keep record of the remaining weapons load after each engagement in order to more realistically model AI recycling and reassignment.

4.3 SURFACE-TO-AIR MISSILE (SAM) CHARACTERISTICS

Currently, SAM sites are considered in the model to operate independently of each other and of the EW/GCI/AI network. Analysis of model results to date indicate that the required SAM netting and control logic in the model would not contribute significantly to model results but would significantly increase model complexity: therefore, this modification is not planned. However, minor modifications of the treatment of such factors as

time between salvos and missile inventory is contemplated.

4.4 DEFENSE EW/AEW/GCI NETWORK

Three areas of modification and/or growth are currently under investigation relative to defense netting. These are: 1) net reaction to decoy discrimination, 2) interfaces (i.e., track handover and communications), and 3) expanded ECM effects on the net. Provisions for the first item have recently been incorporated; however, specific requirements have not yet been determined. The network interfaces are, of course, currently modeled but continuing analyses are being conducted to determine what further refinements are desirable. Specific modifications to include more sophisticated treatment of ECM have not yet been defined. Such effects as multiple targets per strobe, ghosts, false targets, and cumulative noise are under consideration.

4.5 OTHER MODIFICATIONS

A continuing effort is planned to improve the model in terms of use-oriented features. This effort will concentrate on reducing running time, providing additional useful outputs, improving output formats, and minimizing input complications. In conjunction with this effort, a continuing task will be the updating of the user and programmer manuals.